Department of Health
Environmental Health Indicators

Revised June 1998

Washington State Department of
Health
Environmental Health Programs

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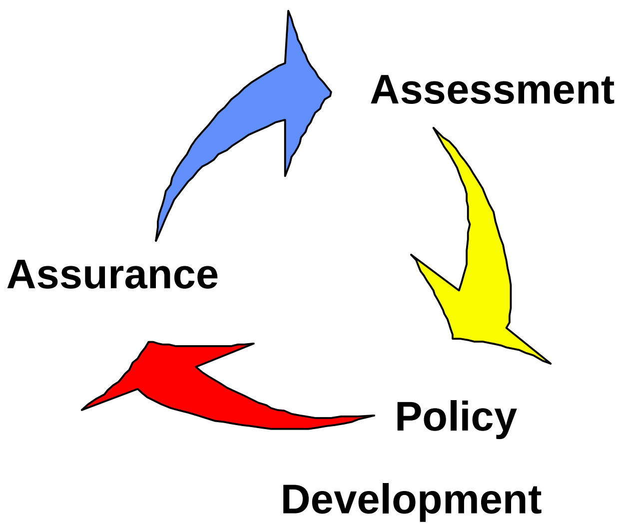
Summary Statement

Public health is continually being impacted by change. Whether the change is in the population or the environment, effective protection requires frequent evaluation and modification of public health effort. One of the greatest challenges in modifying protective practices is to base changes upon a sound assessment of the issues. An integral part of assessing these issues is through the use of indicators. Indicators are measurable elements that are correlated with difficult to measure public health outcomes. Indicators, used in combination with other information, are useful in establishing effective public health policy and enhancing program development. This document provides basic environmental health indicators and addresses factors that require consideration before indicators are applied.

Introduction

The principles for protecting the health of Washington residents are based upon the core functions of public health; assessment, policy development and assurance. These core functions are used to develop policies and program activities in an integrated approach. Assessment activities are used to determine threats to public health, which leads to policy development. Policy development considers alternatives for actions and a course of action to pursue, while assurance is the implementation of policies and making sure the health policies are carried out well.



Indicators can be used in a wide variety of analytical applications across all three core functions. Indicators are an integral part of any assessment strategy for evaluating factors influencing public health. When used concomitantly or with other information, indicators can provide valuable guidance to policy formation and program evaluation and development. Public health protection has benefited greatly through the application of various indicators. As the scale of public health issues continues to expand with emerging illnesses, new hazards, and evolving public health science, there is an increasing demand to develop new indicators that address specific questions. This document provides basic environmental health indicators and addresses factors that require consideration before indicators are applied. Indicators, alone or in combination, are formidable analytic tools that can be used to meet the assessment needs required for protecting public health.

Role of Indicators

Historians generally agree that the first indicator was smoke. In fact, smoke as an indicator of fire was so successful that "Where there's smoke, there's fire" entered the language as a metaphorical truth, and has since attained the status of cliché. The use of indicators to infer knowledge of broader conditions is a long-standing practice in a variety of settings. Physicians can take their patients' temperature and blood pressure to infer certain medical conditions. Economists have tracked unemployment, housing starts, and inflation figures to evaluate the state of the economy. Educators have used the standardized test scores of their students to evaluate the performance of their schools.

The appeal of indicators is that they are measurable. However, their usefulness is limited by the degree to which they correlate with some other, more complicated matter of concern that is not so easily measured. For example, a common practice in environmental health is the use of fecal coliform bacteria levels as an indicator of water contamination from sewage. Fecal coliforms are easily measured, and the presence of fecal coliforms is highly correlated with sewage contamination. The presence of fecal coliforms in water, therefore, represents the condition of water contamination from sewage. However, disease-causing organisms contained in sewage, particularly encysting protozoa and certain viruses, can and do survive in the environment after bacteria die off and become undetectable. So while the presence of fecal coliforms may be a reliable indicator of sewage-contaminated water, caution is warranted because the absence of fecal coliforms is not a reliable indicator of water free of pathogenic organisms.

The prospective uses of public health indicators include a wide variety of analytical applications from routine reporting to program evaluations and community and environmental health assessments. In light of the analytical limitations of indicators, and with this range of applications in mind, this document was developed to provide basic environmental health indicators.

Basic Indicators for Environmental Health

Basic indicators for public health protection from environmental agents were developed along traditional environmental health program areas; drinking water, shellfish protection, radiation protection, food protection, on-site sewage, ambient air, indoor air, water recreation, solid waste, hazardous waste, pesticides, and zoonotic disease. Each program area has its own matrix consisting of basic indicators presented in both column and row format, with accompanying text of supporting information.

The combination of rows and columns can be used as a tool to determine which indicator will best assist in achieving the public health goal of reducing adverse health outcomes. The first column presents the disease, illness or injury, which is to be prevented or minimized by reducing community exposure to environmental hazards. These hazards (second column) are identified directly or through surrogates (third column), with exposure to the hazards minimized through protection measures (fourth column). The rows provide basic indicators that differ from each other, while still associating with disease, illness or injury. By moving within a specific row, relationships between the hazard, public health protection measures and disease, illness and injury are provided. The improvement of public health during this century has demonstrated numerous strong relationships within specific rows; especially between protection measures and health outcomes.

These matrices provide powerful indicators that can be used to meet the assessment needs required for protecting the public health. As environmental conditions change, and as the state of knowledge evolves, the information in the matrices needs to change accordingly. As developed, these indicators, alone or in combination, are formidable analytic public health tools. The users of these tools have much discretion when addressing health issues since a single indicator can be used for less demanding or complicated issues, while indicators in combination can be used to address more complex health issues. A sample matrix and a detailed explanation of the matrix columns follows.

Sample Matrix
Drinking Water Quality Indicators

<table>
<tr><th>Disease/Illness/Injury</th><th>Causative Agent/Hazard (Direct Indicator)</th><th>Indirect Indicator</th><th>Protective Measures</th></tr>
<tr><td colspan="4">Microorganisms</td></tr>
<tr><td>Gastroenteritis, diarrhea, bacillary dysentery, cholera, typhoid fever, gastrointestinal toxicosis, various enteric symptoms</td><td>Bacteria:
E. coli, Vibrio cholerae, Salmonella spp, Yersina spp, Edwardsiella spp, Providencia spp, Arizona spp, others</td><td>Total coliform/fecal coliform (as an indicator of fecal contamination)</td><td rowspan="3">Source selection
Source protection (wellhead, watershed)
Waterworks
Treatment (contaminant removal and prevention)
Cross-connection control
Surveillance (monitoring, technical investigations)
Administration (management, technical, fiscal)</td></tr>
<tr><td>Amebiasis, dysentery, diarrhea, Isoporiasis, meningitis, gastroenteritis, various enteric symptoms</td><td>Protozoa:
Entamoebae histolytica, Balantidium coli, Dientamebae fragilis, Isopora spp, Naegleria, Acanthamoebae, Giardia lamblia, Cryptosporidium, others</td><td>No indicators with a good correlation to cyst-forming protozoa</td></tr>
<tr><td>Viral syndrome, diarrhea, poliomyelitis, hepatitis</td><td>Viruses:
Picornavirus, echovirus, coxackievirus, poliovirus, rotavirus, Norwalk, viral hepatitis groups, others</td><td>No indicators with a good correlation to viruses</td></tr>
</table>

Disease/Illness/Injury, the first column, lists the problems that environmental health programs are designed to prevent. Reported cases of disease, illness, and injury are an indication of some degree of failure in the public health system and may require epidemiological investigations to assess or determine the underlying etiology. The success of various interventions that have improved public health, however, have reduced the number of cases clearly attributable to specific environmental sources to such an extent that the usefulness of some disease data as an indicator is limited. Some disease conditions can be caused by one of several different agents which may come from one of several different sources. Salmonellosis, for example, may occur as a result of exposure through drinking water, food, or pets, and an examination of reported cases may not reveal which exposure media is relevant to the cases. The incidence or prevalence of disease, illness, and injury, however, can be used to measure a community's health status and indicate the possible need for additional assessment, community directed policy development or assurance activities.

Causative Agent/Hazard (Direct Indicator), the second column, lists the microorganisms, elements, chemicals and physical hazards that directly cause the disease, illness, and injury listed in the first column. Where these agents or hazards can be measured or observed in the environment, they are useful as indicators. The shellfish program indicators, for example, include the paralytic shellfish poison (PSP) level in shellfish as a direct indicator in the second column. The PSP level in shellfish is measurable and provides a direct indicator for the potential for PSP illness in humans, should exposure occur.

Indirect Indicators, the third column, lists surrogates for the causative agents and hazards in the second column. These indicators provide information of possible exposure to the causative agents and hazards. When the measurement of a causative agent or hazard is impractical or infeasible, these surrogates may provide an acceptable alternative. Both total coliform and fecal coliform, for example, are easily measured, and correlate well with the enteric bacteria listed in the second column. Counts of total coliform and fecal coliform can therefore serve as indicators of bacterial contamination, and as indirect indicators of the potential for the diseases caused by enteric bacteria.

Protective Measures, the fourth column, lists the interventions designed to prevent or reduce exposures to the causative agents or hazards identified in the second column. Such exposures can lead to the adverse health outcomes listed in the first column. The causative agents or hazards and their surrogates provide a link to these adverse health outcomes. Protective measures, however, are an indicator of a different type because they are mechanisms established to protect populations from exposure to causative agents or hazards. The historical success of environmental health programs in preventing adverse health outcomes amply demonstrates the correlation between certain interventions and the decline in certain diseases, illnesses, and injuries. When these relationships are well known, the protective measures listed in the fourth column allow for public health protection that minimizes the potential for the adverse health outcomes listed in the first column. In the food protection program, for example, the temperature control practices related to the elimination of parasitic exposure are methods of protection that minimize the potential for disease and illness. Proper freezing or cooking, which assumes the presence of the hazard, are the sole means of preventing the occurrence of exposure that can produce deleterious effects. The public health benefit obtained from this type of protective measure far exceeds the benefit obtained from assurance activities and/or other indicators such as meat inspection (third column) to detect if parasites may be present.

Considerations for Applying Basic Indicators

To meet assessment needs, the application of basic indicators, alone or in combination, requires the consideration of certain factors. These factors, when applied appropriately, will enable the user to obtain the powerful tools necessary to effectively engage in community or program assessments, support policy analysis and development, and evaluate assurance activities.

Assessment objective.

Indicators are most effective when a clear objective is established.

Establishing a clear assessment objective is paramount to properly addressing pertinent public health issues. A well defined objective is essential in selecting indicators appropriate for the health issue. For example, obtaining and maintaining drinking water quality is a complex topic. Frequently a single contaminant is used as an indicator of overall water quality. However, there are many contaminants independent of each other that enter the water supply under various conditions. Thus, without a clear objective, indicators are of little benefit for assessing the health issue.

Tailoring the indicator.

Indicators should be tailored to the specific assessment demanded by the public health issue.

Indicators must address a desired endpoint that is associated with minimizing disease, injury or illness. A focused indicator will result in the ability to produce pertinent information that will support the effectiveness of the intervention activity. To illustrate how the selection of an indicator can provide the desired and needed information, an example from the drinking water quality indicator matrix is examined. By selecting the row containing bacterial hazards from the matrix, several different meanings can be derived solely based upon how the indicator was selected. Selecting from the first column could be indicative of failing prevention and acute public health need. Selecting from the second column, could directly indicate the hazard in the environment. The third column, offers an alternative method for evaluating hazards in the environment. Sometimes these indirect indicators take a twist in interpretation and carry with them several different meanings not associated with the direct indicators. Selection from the fourth column, moves away from disease and exposure to prevention and protection. Indicators of protective measures are best described as indicating the completeness of a protection. All four columns have different meanings and should be tailored to meeting the objective demanded by the public health issue.

Availability of information.

Developing an indicator requires that the availability of information be considered.

A great shortcoming in public health protection has been lack of information, particularly as it relates to assessment. For example, many of the diseases associated with water borne illness are not reportable or cannot be attributed to a single source. This lack of information diminishes the value of disease records for protecting the public's health from environmental hazards. At the same time, no effective method has been devised to analyze drinking water for the full array of known bacterial, viral and parasitic pathogens and new pathogens are continuing to be identified. When information is available, however, the public health benefits can be significant. For example, information is available on water borne illness relating to total/fecal coliforms, which are frequently found in water contaminated with sewage. Many health departments and private laboratories provide reliable and inexpensive total/fecal coliform analyses that have provided data used for public health protection. In addition, public water systems are required to report their analytical results to the public. The analysis and required reporting result in a large pool of available information that can be used as an indicator. Often information is lacking. However, availability of information must be considered in developing an indicator even though it may limit the eventual applicability of the result.

Measurement Decisions.

The analytical methods selected and the levels used to distinguish responses can significantly impact the meaning of an indicator.

Depending on the indicator, there may be several measurements and levels of measurements to address.

The principle measurement decision is which method(s) of detection is most suitable for meeting the assessment objective. Using the previous total/fecal coliform example, there is an extensive variety of analytic methods that can be used. For example, different methods are used because some detect at lower levels, while others are only sensitive for certain species or subspecies. As a result, the measurement selection can dramatically influence the capability of the indicator reflecting the assessment objective. Also of importance is using the same method over time for the same objective so that resulting data can be compared and used to provide the greatest possible benefit.

The second measurement decision is how to determine the significance of the measurements. With the previous example, the principle method for coliform analysis of drinking water is presence-absence; either the organisms are detected or not. However, in untreated water, the analysis is usually by most probable number. That is, in untreated water, we often expect and accept a certain level of contamination. As a result, several different thresholds have been adopted in the past, depending upon the objective. Using the same basic indicator, different levels can be selected to associate with various assessment objectives.

Population of Concern.

With public health indicators, it is important to establish what groups are being impacted.

The strength of an indicator is dependent on an identified population of concern. This population consists of those individuals most exposed or most sensitive to deleterious effects from exposure to the causative agent or hazard. Using the total/fecal coliform example; if information on contamination was gathered only from the analytic results reported to the state, only a select portion of the population would be represented. Individuals utilizing private sources of drinking water would have no information available to them regarding possible contamination. Further, if the indicator was protection measure based, the population of concern would be different yet again. As a result, assessment objectives may involve several populations of concern, and these need to be identified prior to applying or developing an indicator.

There are other issues relevant to selecting an indicator, but the critical issue is to properly use indicators as tools to evaluate the specific health issue in question. The example used herein indicates that an impressive variety of indicators can be selected from any given row. This variety is advantageous to public health since each potential indicator has a different interpretation and relates to diverse assessment objectives. Caution is required however, since different interpretations can lead to varying conclusions regarding the objective. Indicators have inherent limitations, and their meaningful use requires an appreciation of these limitations as well as a significant knowledge of the health issues. The widespread use of indicators is not likely to simplify environmental health assessments or program evaluations, but their consistent use and thoughtful application can produce analytical results to guide policy and program development.

Environmental Health Indicators

- Drinking Water Quality
- Shellfish Protection
- Radiation Protection
- Food Protection
- On-Site Sewage
- Solid Waste Exposure
- Water Recreation Protection
- Hazardous Waste Exposure
- Ambient Air Quality
- Indoor Air Quality
- Zoonotic Disease
- Pesticide Exposure

Drinking Water Quality Indicators

Waterborne diseases can be spread through several routes other than drinking water. These include ingestion of food, inhalation, and person to person contact. Frequently, waterborne diseases produce symptoms similar to those resulting from other types of common illness. This similarity in symptomatology makes it extremely difficult to identify drinking water as the source of an illness. In addition, for some waterborne diseases, health effects may not develop until long after the original exposure. It is likely that many unrecognized cases of waterborne illness occur. Considering the known impact of waterborne diseases, strong protective measures must be taken to ensure that these diseases, recognized or not, do not compromise the health status of the community. Of these protective measures, the surveillance for potential health risk indicators is a crucial component of public health protection.

Water Quality

The primary cause of waterborne illness is contamination of the water supply by a variety of chemical substances and microorganisms. In drinking water, any hazardous contaminant present in sufficient quantity represents a potential for illness or disease. As such, each contaminant is an indicator of potential health impact for those individuals served by the water.

Microorganisms
Various pathogenic organisms have been identified as being transmitted by drinking water. *Shigella* bacteria, *Cryptosporidium* protozoa, and rotaviruses are a few of the pathogens known to be responsible for waterborne diseases. While many disease-causing organisms are known, the continued emergence of new waterborne pathogens implies the existence of unidentified waterborne pathogens. Since no feasible method can routinely monitor drinking water for all potential pathogens, indicators for microorganisms must be continually developed that are capable of acting as an indirect indicator for unidentified pathogens, as well as those presently identified.

Most of the pathogenic organisms that affect water quality originate in the gastrointestinal tract of man and other mammals. These pathogens primarily enter the drinking water supply through fecal contamination. With fecal contamination as the most likely source of pathogens in drinking water, surveillance is based upon indicators of fecal contamination. Coliform bacteria, which are commonly found in feces, indicate possible contamination of drinking water by fecal material and also by pathogenic enteric bacteria.

Of the waterborne microorganisms, the life-cycles of coliform bacteria and pathogenic bacteria are similar. However, protozoa and viruses differ from bacteria in life-cycle and resistance. Some viral and protozoan pathogens are capable of persisting in environments not supportive of bacteria. For this reason, coliform bacteria are not a reliable indicator of viral or protozoan contamination. Currently, there is no practical environmental indicator for contamination of drinking water by pathogenic viruses or protozoa.

Inorganic chemicals

Of the inorganic chemicals found in drinking water, several are capable of significantly affecting human health. These chemicals can cause damage to multiple major organ systems in humans.

Industrial pollutants. Hazardous inorganic chemicals tend to enter drinking water from similar sources. These chemicals (antimony, barium, beryllium, cadmium, chromium, cyanide, mercury, nickel, selenium, and thallium) are commonly used in mining operations; metal processing and finishing; painting; textile manufacturing; the production of alloys; glass; and fertilizers. In addition, these chemicals can occur in natural geologic formations. As a group, the presence of these chemicals is an indirect indicator of industrial pollution in a water supply.

Nitrate. Elevated levels of nitrate can lead to methemoglobinemia, a potentially fatal blood disorder that is characterized by interference with the blood's capacity to transport oxygen. This disease predominantly affects the health of infants, although certain adults may be predisposed to the adverse effects of nitrates at higher levels. Symptom onset can occur promptly after exposure to nitrate. The principal sources of nitrate contamination in drinking water are from agricultural activity, solid waste, decomposing vegetation, and naturally occurring geologic formations. While nitrate is a direct indicator for its health effects, it is also an indirect indicator of other health hazards, such as pathogenic organisms and organic chemicals that can be introduced into water from the same sources of contamination.

Lead. Lead's most significant health impact is on the mental development of children. Lead enters drinking water supplies either from natural geologic formations or the corrosion of plumbing fixtures containing lead. Drinking water is but one of many potential sources of this contaminant. Health effects are influenced by the combined exposure to lead from all sources, including drinking water. Due to the multimodal nature of lead exposure, lead in drinking water may not be an effective indicator of the health effects of lead.

Copper. Like lead, copper enters drinking water primarily from the corrosion of copper containing plumbing fixtures or from natural geologic formations. Ingestion of high levels of copper can lead to gastrointestinal symptoms, particularly among the very young and those with irregular absorption and metabolism of copper.

Fluoride. Fluoride, which occurs naturally at low levels in most ground water, is a common drinking water additive. Many municipal water systems adjust the fluoridation into a range which produces a health benefit by reducing dental caries among children. Within the therapeutic level, fluoride is considered to promote health. At elevated levels, fluoride has been associated with fluorosis and the weakening of dental and skeletal structures.

Arsenic. Ingestion of excess amounts of arsenic via drinking water can produce acute and chronic illness and death. Most water supplies contain trace levels of arsenic which enters the water from either natural sources or as the result of human activity. Mining, pesticides and glassware manufacturing have been principal industrial sources of arsenic. However, the infiltration of ocean water into fresh water aquifers can also be a source of arsenic in drinking water.

Organic chemicals

Organic chemicals are widely used for a variety of purposes in industry, agriculture, and the household. Under a variety of conditions, these chemicals can be discharged into a water supply. Individuals consuming contaminated drinking water could develop acute or chronic illness. Many organic chemicals are hazardous to human health, damaging major organ systems or potentially causing cancer. However, the human health effects for most organic chemicals have not been well described.

As the number of hazardous organic chemicals continues to rapidly expand, it is not feasible to monitor for each chemical compound. Yet, it is feasible to perform routine surveillance for selected organic chemicals. The organic chemicals selected for surveillance are commonly used solvents, degreasers, fuel components, soil fumigants, and pesticides. Each contaminant under surveillance is a direct indicator of its health effects and represents the indirect indicator of a much more expanded frame of contaminants. With the progress in development of new organic chemicals, the use of the currently selected compounds as indicators may be inadequate. For this reason, the selection of organic chemical indicators may need to be expanded.

Commonly used disinfectants, such as chlorine, react with naturally occurring organic substances to form a family of organic compounds referred to as disinfectant by-products. The illnesses related to these compounds include a variety of acute and chronic toxic effects. An extensive list of disinfectant by-products, already exceeding one hundred, has been identified. Yet, not all of the disinfectant by-products are known. The trihalomethanes and haloacetic acids, which are disinfectant by-products themselves, are indirect indicators of the entire class of potentially hazardous disinfectant by-products.

Radionuclides
See Radiation Protection Indicators.

Measures Protective of Water Quality

Prevention of the adverse health impacts produced by contaminants is primarily achieved through protecting the drinking water supply from contamination. The adequacy, reliability, and safety of drinking water is assured through a broad spectrum of protective measures.

Source protection
Of the possible points where a water system could be contaminated, the source is most vulnerable. Source water is often drawn from a watershed, aquifer, or basin over which the water system has little control. Contaminated water supplies are expensive, and sometimes impossible, to treat or replace. As a result, acquiring and maintaining a high quality drinking water supply, centers around protecting the source water. Source protection programs, such as wellhead protection and watershed protection, involve identifying the source of the water, inventorying the area for potential sources of contamination, and managing them to minimize future pollution problems that might affect the drinking water supply.

Waterworks

Susceptibility to contamination is influenced by the design, components, and method of construction used by a water system. Improperly built water systems may provide unreliable service, produce insufficient quantities of water, and develop problems with contamination. In order to protect the drinking water supply, water systems must comply with appropriate design standards.

Cross connection

A connection between the water distribution piping and other plumbing, such as waste water pipes and fire sprinklers, is a cross connection. When the normal flow of water is reversed, back pressure or back siphonage can allow contaminants to enter the drinking water through the cross connection. The prevention and elimination of potential cross connections is crucial in the prevention of contamination.

Treatment

Contamination of drinking water cannot always be avoided. With contamination, public health protection requires some form of health risk mitigation. Water treatment processes, although dependent upon several variables, are designed for the removal, reduction, or prevention of specific forms of contamination. These treatment processes may be only partially effective. In addition, many treatments cannot be continually operated with full effectiveness. For these reasons, some contaminants may require several treatment processes or a multiple barrier protection technique.

While some treatment of source water is appropriate for the removal or attenuation of hazardous contaminants, other treatment prevents the introduction of hazard in the distribution system. Regrowth of microorganisms, corrosion of piping materials, and leaching of chemicals from contact surfaces are potential sources of drinking water contamination within a water system amenable to prophylactic treatment. However, for some contaminants, treatment is not feasible or only partially effective.

Even though the treatment process functions to protect the public health, it can introduce into the water, substances capable of having adverse health impacts. Specifically, the health effects of protective chemicals and the by-products of their use must be considered in the selection of treatment processes. As a result, a balance between the risks associated with exposure to pathogenic organisms versus the possible health effects of disinfectants and their by-products must always be achieved.

Surveillance

The technical investigator inspects and evaluates the public health aspects of a water system's operation. This investigation reveals the sanitary operational practices that adversely affect water quality and reliability of service. In addition to investigation of system operation, surveillance includes the routine monitoring of water quality for contamination.

Administration
A viable public water system has the managerial, technical, and financial capabilities to consistently provide safe drinking water on a long term basis. The water systems that are least capable of providing continuous, reliable and appropriate protection of the drinking water pose the greatest potential risk to the public's health. The proper administration of a water system provides the infrastructure necessary for the protection of the public's health.

Access to Public Health Protection

Water is one of the most basic human needs. Personal use of water includes drinking, cooking, sanitation, and hygiene. As a result, access to adequate amounts of safe drinking water for multiple purposes is essential for maintaining good health. If the supply of water is inadequate, the water system may not be capable of safe operation and may become contaminated. When a water supply is not dependable, people may turn to other unsafe sources. Access to a drinking water resource, today and in the future, depends upon planning by water system purveyors and government officials to meet the evolving drinking water needs of the community. Beyond planning, appropriate action must ensure the continued availability of drinking water.

Many factors affect the degree of public health protection provided to those consuming drinking water. The provision of safe, adequate and reliable drinking water is the responsibility of the water supplier. The capacity of the supplier to achieve and maintain this provision, combined with the degree of assurance provided by public health programs, determines public health protection.

Assurance of health protection by a public health program frequently relies upon regulation and oversight. However, there is little oversight related to the operation of private water supplies, which are excluded from many health regulations. For these private systems, assurance of public health protection is primarily the responsibility of the well owner. The ability of the well owner to prevent problems and resolve health issues is the health protection for these systems. The availability of programs and information to enhance a well owner's capabilities equates to improved health protection.

Drinking Water Quality Indicators

isease/Illness/Injury	Causative Agent/Hazard (Direct Indicator)	Indirect Indicator	Protective Measures
	Microorganisms		
nteritis, diarrhea, bacillary ry, cholera, typhoid fever, testinal toxicosis, ı, various enteric ns	**Bacteria** *E. coli, Vibrio cholerae, Salmonella spp, Shigella spp, Yersina spp, Edwardsiella spp, Providencia spp, Arizona spp*	Total coliform/fecal coliform (as an indicator of fecal contamination)	Source Selection Source Protection (wellhead and watershed protection) Waterworks (design, operation) Treatment (contaminant removal/attenuation, prevent further contamination) Cross-Connection Control Surveillance (monitoring, technical investigations) Administration (management, technical, fiscal)
sis, dysentery, diarrhea, osis, meningitis, ıteritis, various enteric ns	**Protozoa** *Entamoeba histolytica, Balantidium coli, Dientamebae fragilis, Isospora spp, Naegleria, Acanthamoebae, Giardia lamblia, Cryptosporidium*	No indicators with a good correlation for cyst-forming protozoa	
yndrome", diarrhea, elitis, hepatitis	**Viruses** Picornavirus, echovirus, coxackievirus, poliovirus, rotavirus, Norwalk, viral hepatitis groups	No indicators with a good correlation to viruses	
	Inorganic Chemicals		
ıaglobinemia	Nitrate		Source Selection Source Protection Waterworks (design, operation) Treatment (contaminant removal/attenuation, prevent further contamination) Cross-Connection Control Surveillance (monitoring, technical investigations) Administration (management, technical, fiscal)
nd chronic toxic effects ıg damage to the renal and systems, cancers	Arsenic		
r chronic toxicity, cancer	**Industrial Pollutants** Antimony, barium, beryllium, cadmium, chromium, cyanide, mercury, nickel, selenium, and thallium		

isease/Illness/Injury	Causative Agent/Hazard (Direct Indicator)	Indirect Indicator	Protective Measures
nervous system effects, d mental development	Lead	Lead, copper analysis (90th percentile tile lead level is indicative of drinking water portion of the exposure only)	Building Codes Waterworks (design, operation) Treatment (contaminant removal/attenuation, prevent further contamination) Surveillance (monitoring, technical investigations) Administration (management, technical, fiscal)
ntestinal distress	Copper		
is er, fluoride reduces dental	Fluoride		Waterworks (design, operation) Treatment (contaminant removal/attenuation, prevent further contamination) Surveillance (monitoring, technical investigations) Administration (management, technical, fiscal)
		Organic Chemicals	
nd chronic toxic effects g damage to the renal and systems, cancers	**Volatile Organic Chemicals** Benzene, carbon tetrachloride, dichlorethane, vinyl chloride, styrene, toluene, xylene	Results from the Volatile Organic Chemical (VOC) source contaminant panel (Method 524.2)	Source Selection Source Protection Waterworks (design, operation) Treatment (contaminant removal/attenuation, prevent further contamination) Cross-Connection Control

isease/Illness/Injury	Causative Agent/Hazard (Direct Indicator)	Indirect Indicator	Protective Measures
nd chronic toxic effects ıg damage to the renal and systems, cancers	**Older Synthetic Organic Chemicals with historic use** Alachlor, atrazine, Chlordane, Dalapon, Diazanon, Dinoseb dibromochloropropane, Diquat, 2,4-D (Weedar 64), Endothall, Endrin, ethylene dibromide, Heptachlor, Lindane, Malathion, Methoxychlor, naphthalene, pentachlorophenol, PCBs, Toxaphene, 2,4,5-TP (Silvex)	Results from the Synthetic Organic Chemical (SOC) source contaminant panel (Method 525.2)	Surveillance (monitoring, technical investigations) Administration (management, technical, fiscal)
acute or chronic toxic	**New Synthetic Organic Chemicals in current use** Trifluralin, methylbromide, Methomyl, Picloram, Cyanazine, EPTC, butylate, Zineb		

isease/Illness/Injury	Causative Agent/Hazard (Direct Indicator)	Indirect Indicator	Protective Measures
acute or chronic toxic	**Disinfectant By-Products** Trihalomethanes, haloacetic acids, haloacetonitriles, cyanogen halides, halopicrins, chloral hydrate, halophenols, haloaldehydes, haloketones	Trihalomethanes, haloacetic acids	Source selection Treatment (contaminant removal/attenuation, prevent further contamination) Surveillance (monitoring, technical investigations)
		Radionuclides	
see Radiation Protection ırs	Radium 226 Radium 228, Strontium 90, Tritium Uranium	Alpha, gamma Beta Alpha, beta, gamma	Environmental surveillance, source control
see Radiation Protection ırs	Man made Radionuclides	Alpha, beta, gamma	Surveillance (monitoring, technical investigations)

Shellfish Protection Indicators

Illness caused by the consumption of molluscan shellfish results from filter-feeding shellfish picking up natural biotoxins, natural bacteria, and microbial constituents of fecal pollution from growing waters. Theoretically, chemical pollutants could also pose a risk of causing illness if absorbed by shellfish growing in waters contaminated from industrial processes.

Natural Biotoxins

Illness caused by the natural biotoxins of phytoplankton can be fatal. There are two varieties of natural biotoxins found sporadically in Northwest waters. They are paralytic shellfish poison (PSP) and domoic acid (causing amnesic shellfish poisoning). The direct indicators of the environmental hazards are the levels of these natural biotoxins in shellfish meats. Samples of various molluscan shellfish are routinely collected for analysis to monitor biotoxin levels. Commercial harvest areas are closed and warnings are issued to the public when biotoxin levels are elevated. An indirect indicator of the biotoxins in shellfish is the concentration of toxic varieties of phytoplankton in marine waters. However, counting phytoplankton is not a standard monitoring method for determining PSP or domoic acid concentrations in shellfish.

The primary methods used to protect the public from biotoxins are operational controls, which can be monitored. One operational control is the seasonal closing of shellfish harvesting in certain geographic areas where natural biotoxin levels are normally high. For example, the Pacific Ocean coast during the summer and early fall is closed to harvesting because of consistently elevated levels of PSP. Another protective measure, applicable to shellfish imported into Washington, is the requirement that shellfish come from a source certified by an agency participating in the National Shellfish Sanitation Program (NSSP). Monitoring by out of state agencies participating in the NSSP provides the sole protection against varieties of natural biotoxins not found in Northwest waters.

Bacteria Natural to Environment

Illness caused by bacteria natural to shellfish growing waters can vary in severity from fairly mild to life threatening and include gastroenteritis, septicemia, and botulism. The direct indicators for the environmental hazards are the levels of the various pathogenic bacteria in the products. The bacteria multiply in the products when conditions are favorable, such as warm temperature conditions for *Vibrio* species. Monitoring the direct bacterial indicators is expensive and time consuming. As a result, an indirect indicator is used, which consists of monitoring the storage temperature of product after harvest. Refrigeration temperatures prevent low natural levels of bacteria in shellfish from increasing to high, potentially hazardous, levels.

One significant natural bacterial pathogen, *Vibrio vulnificus*, which causes septicemia and tissue necrosis, is not found in Northwest waters. However, it is common in shellfish from the Gulf of Mexico. There is a gap in protection against this agent because monitoring by out of state agencies participating in the NSSP is not dependable. Limiting harvest to the colder months of the year, when levels of natural bacteria are low, could indirectly control the hazard, but is a control measure unacceptable to many shellfish producing states. Education of the public, especially highly susceptible groups of individuals, about natural bacterial hazards is an underutilized protective measure.

Microbes Associated with Fecal Pollution

Illness can be caused by microbial constituents of fecal pollution in shellfish growing waters. The microbial agents include bacteria and viruses. The diseases range in severity from typhoid fever and hepatitis A to mild viral gastroenteritis. The direct indicators of the environmental hazards are the microbial agents themselves. However, monitoring shellfish meats or growing waters for bacterial agents is time consuming and expensive. Monitoring for viral agents is so difficult and expensive it is essentially impossible. As a result, an indirect indicator, fecal coliform Most Probable Number (MPN), is used to monitor levels of microbial pollutants in growing waters. The fecal coliform level is a better indicator of bacterial agents of disease than it is of viral agents. Fecal coliform levels are generally proportional to, or higher than, levels of pathogenic bacteria in waters with fecal pollution. However, fecal coliform levels are not an accurate indicator for viruses because coliform levels frequently are not proportional to levels of pathogenic viruses. Pathogenic viruses can survive longer in water than fecal coliforms and are affected less by disinfectants.

Several protective measures, which are operational controls, are monitored as indicators of microbial pollutants in shellfish growing waters. Sanitary surveys of shorelines are used to detect such pollution sources as failing on-site wastewater disposal systems around the growing areas. The location and distance to sewage plant outfalls, marinas, and boat moorage areas determine point sources of pollution. Refrigeration after harvest is a protective measure to prevent multiplication of bacteria in shellfish meats.

Chemicals Associated with Pollution

Illness that might be caused by chemical pollutants absorbed by shellfish has not been identified in Washington. Theoretically, acute and chronic diseases could be caused by consuming shellfish contaminated with chemical pollutants from industrial discharges or surface water runoff from municipal areas. Toxic contaminants in shellfish are the direct indicators of the environmental hazard. They can be monitored in shellfish meats and growing area sediments, but are not monitored as a routine practice. Testing for chemical pollutants is expensive and there are no appropriate indicators for the multitude of compounds that might be of concern, other than the chemicals themselves. A practical protective measure is to restrict harvest based on the current and historical industrial use of areas surrounding shellfish growing waters. In industrial areas, commercial harvest is prohibited and the public is educated about possible hazards of recreational harvest.

Access to Public Health Protection

The limitations of public health protection activities for shellfish primarily relate to recreational and subsistence harvesting. The protective programs are designed to assure that shellfish harvested from commercial areas or from recognized public beaches are reasonably safe for consumption. Large areas of marine shoreline outside of those two categories are not regularly monitored. Waterfront property owners and tribal members are not provided protective monitoring unless they harvest from growing waters overlapping the commercial areas or recognized public beaches.

Types of shellfish of little or no commercial significance are not part of regular monitoring programs. Other species cannot be monitored fully. For example, the Puget Sound scallop resource has about $100,000 of commercial value. It would require a complex and expensive program to monitor scallops because of the free-living nature of these animals in deep waters and the need to have divers collect them. The small size of the scallop resource makes it unreasonable to implement a protective program for either the commercial or recreational harvest for all areas where scallops are found. However, a potential hazard from scallops exists because they tend to absorb PSP faster and to higher levels than other shellfish. The phytoplankton that produce PSP biotoxin multiply to high levels sporadically, resulting in great variation in concentration over small amounts of time and geographic area. Therefore, commercial harvesting is allowed in only certain limited areas where PSP levels are monitored specifically in scallops. The public is advised that regulatory agencies cannot assure the safety of Puget Sound scallops and that they should not be collected recreationally during the portion of the year (July - November) when PSP levels are frequently elevated.

Public education about seafood safety could provide a great deal of public health protection. Most of the shellfish-related illness reported in Washington State is caused by a type of bacteria natural to marine waters: *Vibrio parahaemolyticus*. The bacteria multiply to high levels in marine waters in the summer and to even higher levels in shellfish if not kept cold after harvest. Recreational harvesters have little or no concept of this hazard. There is no way to assure that shellfish are safe if consumed raw. The degree of risk increases with the temperature of the growing waters. Commercially harvested shellfish also present some risk. It is impossible for control programs to assure the product has been kept cold. "Sell by" dates on shucked fresh product are set by the industry and may be too long, in some cases, to assure safety. Shellfish harvested during the summer from the Gulf of Mexico and Atlantic coast of the southern United States are particularly hazardous. They frequently contain a more deadly type of naturally occurring bacteria, *Vibrio vulnificus.* Therefore, the best public health measure may be to advise people that it is safer to eat shellfish cooked rather than raw, especially in the summer.

Information provided by public health agencies may not be understood by some recreational harvesters resulting in inadequate public health protection. The PSP toll-free hotline has a 24-hour a day message advising the public where PSP levels have been measured to be high. However, the message is only in English. Also, other public warnings passed through the mass news media about PSP levels might not reach individuals who cannot speak English. Beach warning signs about PSP or pollution hazards are frequently in multiple languages, but some recreational harvesters may not be able to read any languages.

Shellfish Protection Indicators

ase/Illness/Injury	Causative Agent/Hazard (Direct Indicator)	Indirect Indicator	Protective Measures
	Natural Toxins		
ss gic/muscular)	Paralytic shellfish poison levels in shellfish	*Alexandrium catenella* phytoplankton levels in growing waters	Harvest restricted during certain seasons of year
shellfish poisoning gic/systemic)	Domoic acid levels in shellfish	(*Pseudonitzschia spp.* phytoplankton levels in growing waters)	
gic/systemic effect	Levels of other toxins in shellfish	Other phytoplankton not significant in NW	Approved by out of state NSSP agencies
	Bacteria Natural to Environment		
teritis ia . ecrosis	*Vibrio parahaemoliticus* *Vibrio cholerae non-01* *Listeria monocytogenes* *Clostridium botulinum* (type E) *Vibrio vulnificus* (not found in NW)	Storage temperature after harvest (especially after vacuum packaging) Temperature of growing waters (season of year/geographic area)	Education of public Critical shellfish handling and storage procedures after harvest (e.g. cold temperature)
	Microbes Associated with Fecal Pollution		
 fever teritis y	**Bacteria** *Salmonella spp.* *Vibrio cholerae 01* *Campylobacter jejuni* *Shigella dysenteriae* Enteropathogenic *E. coli*	Fecal coliform MPN in growing waters	Approved by out of state NSSP agencies Sanitary survey along shoreline to monitor for failing on-site wastewater systems No sewage plant outfall in growing waters No marina/boat moorage in growing waters Critical shellfish handling and storage procedures after harvest (e.g. cold temperature) Sanitary survey along shoreline to monitor for failing on-site wastewater systems No sewage plant outfall in growing
   teritis	**Viruses** Hepatitis A and E Polio Norwalk, astrovirus	Fecal coliform MPN in growing waters (relationship to viruses variable)	

			waters No marina/boat moorage in growing waters
Chemical Pollutants			
d chronic toxicity	Industrial chemicals	History of growing area	Avoiding growing waters near industrial areas

Radiation Protection Indicators

All Washington residents are exposed to radiation. Sources of radiation are of two general types; those of natural origin, including background radiation and radiation enhanced by industrial processes, and those of artificial (man-made) sources, which are manufactured for a wide variety of uses. For both types of sources, there are ionizing and non-ionizing forms of radiation. The best documented injury associated with radiation exposure is the alteration of genes and chromosomes. The most significant biological effect is damage to DNA, thereby affecting the reproductive mechanism of the cells. In some cases this damage causes uncontrolled cell growth leading to cancer.

Direct and Indirect Indicators

Natural radiation
Natural ionizing radiation. Ionizing radiation from natural sources are direct indicators, and include: cosmic and cosmogenic radiation (from space), terrestrial radiation (from radioactive sources and their decay products found in the earth), and radionuclides from inside the body (mainly potassium 40). Human exposures to natural sources have been increased as a result of human actions. These include activities such as high altitude air travel and various mining and industrial activities. Cosmic and cosmogenic radiation varies with altitude. Radiation exposure from terrestrial sources is somewhat higher in areas of higher mineralization such as the central and northeastern parts of Washington, but doesn't differ significantly from the national average. Radon 222, a terrestrial source of radiation, is the most significant natural source of human exposure. Approximately 100,000 state residents may be exposed to radon levels exceeding the Department's guidance of 10 picocuries per liter. The indirect indicators for ionizing radiation are alpha, beta, and gamma emissions which are routinely measured as part of environmental surveillance programs.

Natural non-ionizing radiation. Non-ionizing radiation from natural sources are direct indicators and consist of ultraviolet rays from the sun and radio frequency (RF) waves from outer space. Ultraviolet exposure varies with altitude and meteorological conditions. Exposure from natural RF is essentially constant throughout the world and contributes little, if any, of the total non-ionizing radiation dose received by the population. No indirect indicators are available for non-ionizing radiation from natural sources.

Artificial radiation
Artificial, ionizing radiation. Artificial sources of radioactive materials and devices are responsible for various direct effects including cancer, acute radiation burns and genetic alterations. Many of the exposures from these artificial sources of radioactive materials and devices occur in the medical field. Along with the x-ray machines used for diagnosis, there are also radiopharmaceuticals used for diagnosis or treatment such as iodine 131 and technitium 99m. Exposure of patients is deliberate and directly benefits the individuals exposed; whereas,

cumulative inadvertent exposure to medical personnel may be hazardous. Medical x-rays contribute the majority of the ionizing radiation dose to individuals from artificial sources. Another source of exposure to ionizing radiation comes from industrial uses of radioactive materials and occurs mostly in occupational settings. Applications such as radiography, nuclear power, waste management, national defense programs, and some research activities are the principal industrial sources that contribute exposures to radiation workers.

The indirect indicators for ionizing radiation are alpha, beta and gamma emissions which are routinely measured as part of surveillance programs. Environmental surveillance is performed at all facilities with known or suspected off-site impact.

Artificial, non-ionizing radiation. This form of radiation can produce burns and includes, as direct indicators, low frequency waves, ultraviolet waves from tanning booths and radio frequencies. No indirect indicators are available for this form of radiation.

Protective Measures

Protective measures for artificial sources of radioactive materials and devices used in the medical field include federal and state regulatory programs that seek to minimize exposures to patients while still achieving adequate treatment. Protective measures for minimizing exposure to ionizing radiation from industrial and military uses of radioactive materials consists of regulatory programs conducted by the Washington State Department of Health, the U.S. Nuclear Regulatory Commission, the U.S. Environmental Protection Agency, and the U.S. Department of Energy. In addition to license or permit conditions, many of the programs include active emergency planning and preparedness requirements.

Individuals in occupational settings obtain a large percentage of their average radiation exposure from the facilities using artificial sources. Protective measures minimizing exposure to radiation sources are most often applied to these specific facilities. Protective measures are also provided through the setting of radiation standards that are many times below the levels where health effects are measurable. This is accomplished using the ALARA (as low as reasonably achievable) concept, which lowers exposure levels so as to be well below those required by regulatory standards.

Other protective measures include time, distance and shielding, which are used to provide worker safety when dealing with radioactive materials. Education remains the primary protective measure used to address health effects from artificial and natural radiation, especially for indoor radon.

Access to Public Health Protection

There are currently no health regulations in place to control the uses of non-ionizing radiation, which may impact some populations. The Department, however, maintains a clearinghouse of information on research in the field, which is used to provide guidance on health effects upon request. Currently there are no state education programs that address the health effects of indoor radon and how to minimize exposure. As a result, there may be individuals in our state who are under served.

Radiation Protection Indicators

se/Illness/Injury	Causative Agent/Hazard (Direct Indicator)	Indirect Indicator	Protective Measures
	Natural Ionizing Radiation		
iation effects ffects	**Terrestrial** -Uranium, thorium -Radium 226 -Potassium 40 -Radon 222	 Alpha, beta, gamma Alpha, gamma Gamma Alpha	 Education and environmental surveillance, building codes, ventilation, and construction barriers
	Mining & Milling -Uranium, thorium -Radium 226 -Radon 222	 Alpha, beta, gamma Alpha, gamma Alpha	Licensing conditions, containment, land use limitations, and environmental surveillance
	Cosmogenic -Carbon 14, tritium -Beryllium 7, sodium 22	 Beta Gamma	Education
	Cosmic	Neutrons, muons, electrons	Education
	Natural Non-Ionizing Radiation		
a	**Ultraviolet Waves** **Radio Frequency Waves (Cosmic) (30khz-300 ghz)**		Education and shielding (sun block) UV)
	Artificial, Ionizing Radiation		
  iation effects ffects	**Medical Diagnostic & Therapeutic** - Technetium 99m, iodine 131, thallium 201, cesium 137, cobalt 60, iodine 125 - Xenon 133, strontium 89 - Phosphorous 32	 Gamma Beta, gamma Beta	Time, distance, shielding, containment, air operating permits, and licensing conditions
	Medical (Machine generated) Industrial (Sealed Sources, Machine Generated) - Americium 241/beryllium - Cobalt 60, cesium 137, cobalt 57	 Alpha, neutron Gamma	

se/Illness/Injury	Causative Agent/Hazard (Direct Indicator)	Indirect Indicator	Protective Measures
	Laboratories - Iodine 131, iodine 125, chromium 51 - Carbon 14, tritium, phosphorous 32	 Gamma Beta	Time, distance, shielding, containment, air operating permits, and licensing conditions
iation effects	**X-Ray Machines**	X-ray	X-ray tube registration, inspections, education, building code/plan review
ffects	**Consumer Products** - Nickel 63, tritium - Americium 241 - Polonium 210	 Beta Gamma Alpha	Control of manufacturing and distribution
	Low Level Waste - Tritium - Cesium 137, cobalt 60 - Radium 226	 Beta Gamma Alpha, gamma	Licensing conditions, air operating permits, containment, environmental surveillance, and closure plans
	High Level Waste - Strontium 90 - Cesium 137, americium 241 - Plutonium 239/240 - Explosive mixtures	 Beta Gamma Alpha Temperature, hydrogen	Air operating permits, program audits, emergency planning, and environmental surveillance
	Federal Facilities - Strontium 90 - Cesium 137, americium 241 - Plutonium 239	 Beta Gamma Alpha	Air operating permits, program audits, emergency planning, and environmental surveillance
	Reactors - Iodine 131, cesium 137 - Krypton 85	 Gamma Beta, gamma	NRC operating license, EFSEC site certification agreement audits, environmental surveillance, and emergency planning
	Artificial, Non-Ionizing Radiation		
a	**Electro-Magnetic Waves (EMF)** - Extremely low frequency waves (60 hz) (ELF) - Radio frequency waves (30khz-300ghz) - Ultraviolet waves (tanning booths)		Time, distance, shielding, and education Siting of transmission lines, education, zoning, and building codes

Food Protection Indicators

A great variety of microorganisms, chemicals, and natural toxins can cause illness when consumed in food. The indicators for the shellfish and water programs can also be considered indicators for the food program. Shellfish are a type of food and water is a common ingredient in food. There are few practical indirect indicators of the causative agents. Food worker training is an important protective measure against most of the causes of foodborne illness.

Natural Biological Toxins

Illness can be caused by natural biological toxins found in food items, including certain plant leaves, roots, fruits, grains, mushrooms, molds, and fish. For example, certain tropical and subtropical fish varieties may concentrate natural toxin (ciguatera) from their food supply. Natural biotoxins in food are associated with various injuries including liver, gastrointestinal, neurological, cardiovascular, and renal. Another example of a potentially toxic food is peanuts moldy with A*spergillus.* This mold produces aflatoxin, which is a potent carcinogen. Bacterial decomposition can cause constituents of certain foods to become toxic. Histidine, a non-toxic component of proteins found in high amounts in some varieties of fish, can be converted to histamine by common non-pathogenic bacteria. Histamine causes reactions in consumers similar to an acute allergic response. Spoilage is an indirect indicator of histamine in the appropriate fish varieties, and of mold toxins in numerous foods. Protective measures against natural biological toxins include training harvesters and marketers to identify and reject varieties of toxic plants, mushrooms, and fish; proper dry storage of grains; and cold temperature storage of fish.

Chemicals Other Than Natural Biotoxins

Various toxic chemicals can enter foods during growing, harvesting, processing, storage, or distribution. Pesticides, other man-made organic chemicals, cleaning chemicals, heavy metals (e.g. copper, lead, and mercury), and intentional food additives (e.g. MSG and sulfites) can cause a myriad of harmful responses, ranging from mild (e.g. headaches) to severe (e.g. fetal injury, neurologic disorders, and liver damage). Good indirect indicators of chemical contaminants in food, which can be monitored routinely by food safety professionals, do not presently exist. Certain organic chemicals and oils used as carriers for some pesticides have noticeable odors. Whereas, heavy metals can produce colors or flavors. Protective measures against toxic chemicals include obtaining food from sources that are properly licensed by federal or state agencies; labeling chemicals for proper use on or around food; using food containers made of safe materials; protecting the water supply from industrial pollution and cross-connections; and educating the public about food sensitivities and allergies.

Microorganisms

Only hermetically sealed containers (e.g. cans) of sterilized food are free of microorganisms. Most microorganisms commonly found in food are harmless. Some impart beneficial properties to food, while others inhibit the growth of hazardous microorganisms. However, there are a wide variety of microorganisms that can produce illness through food consumption. These harmful microorganisms enter food from animal sources, human food handlers, and the environment.

Bacteria from animal sources

Meat, milk, and eggs frequently contain bacteria that are pathogenic for humans. The bacteria usually originate from the intestinal tract of the producing animal. During slaughter, the carcass can become contaminated with animal fecal matter. Milk can contain bacteria from fecal contamination or from udder infections. Animal manure can contaminate vegetables and fruits. Eggs can become contaminated during formation in the chicken. *Campylobacter jejuni*, *Salmonella spp*., *Escherichia coli*, and *Yersinia enterocolitica* are the most common bacteria derived from animals that cause serious foodborne illness. These bacteria can produce illness by infecting the consumer's gastrointestinal system and possibly spreading through the bloodstream. Symptoms most commonly include nausea, vomiting, diarrhea, abdominal cramps, and fever. Enterohemorrhagic strains of *E. coli* can cause bloody diarrhea and widespread organ damage. The presence of phosphatase can be used as an indirect indicator for these pathogens in milk. No indirect indicator is used for meat. Protective measures against these bacteria include milk pasteurization; refrigeration; thorough cooking; preventing cross-contamination of ready to eat products from raw animal products; washing vegetables and fruits; and preparing food using a water supply protected from contamination. Reheating food before serving is a secondary protective measure.

Parasites from animal sources

Meat can contain parasites in the flesh of the slaughtered animal. Trichinosis is a serious parasitic disease acquired from eating pork, bear meat, and other more exotic omnivorous or carnivorous mammals. The tiny *Trichinella* roundworms cause pain as they migrate from the intestine of the consumer to settle in muscle tissues. Other varieties of roundworms can be acquired from fish. Tapeworms can be acquired from beef, pork, and fish. Except for *Trichinella* and the pork tapeworm, the worms remain in the alimentary tract and usually produce mild symptoms. Tapeworm and roundworm life stages in animal flesh can often be seen by inspection. The most effective protective measure against tapeworms and roundworms is thorough cooking of meat and fish. Hard freezing can also kill the worms.

Giardia and *Cryptosporidium* are protozoan parasites that can get into food from animal fecal contamination of water or vegetables. They produce gastrointestinal symptoms primarily. *Toxoplasma gondii* is a protozoan parasite that can infect humans through many types of meat or through the feces of cats. It causes systemic infection that is usually mild in adults, unless immunocompromised, but is life-threatening for fetuses. There are no indirect indicators for the protozoan parasites. Protection measures against *Giardia* and *Cryptosporidium* are washing vegetables and using water supplies for food preparation that have been protected from animal fecal contamination. Protection against *Toxoplasma* is provided by thorough cooking of all meat and good handwashing between cat litter box contact and food preparation.

Bacteria from food handlers

Pathogenic bacteria that are shed by infected food workers in their feces can contaminate food because of poor hygiene practices of the food workers. Bacteria transmitted in this manner include *Campylobacter jejuni*, *Salmonella* spp., *Escherichia coli, Shigella* spp., and *Vibrio cholerae*. The diseases they produce are infections that range in severity from gastroenteritis to typhoid fever. Bloody diarrhea and life-threatening multiple organ damage can be caused by the enterohemorrhagic strains of *E. coli*. There are no good indirect indicators for these causative agents in food. Protective measures against these fecal bacteria include food handlers practicing thorough handwashing after using the restroom, preventing direct hand contact with ready to eat food, and refrigerating food to prevent the multiplication of bacteria that might have been added to it by food handlers. Reheating food before service is a secondary protective measure. *Staphylococcus aureus* (staph) is a variety of pathogenic bacteria commonly on the hands, especially in cuts, and in the noses of healthy food workers. Staph can be added to food by hand contact or sneezing. *Streptococcus* Group D (strep) is a variety of bacteria that primarily cause respiratory tract infections. Strep can be added to food by coughing, sneezing, or hand contact. Staph and strep produce toxins while multiplying in food at room temperature. The toxins cannot be destroyed by reheating the food. The toxins produce gastroenteritis characterized by violent vomiting. There are no indirect indicators for these causative agents that can be used at reasonable cost. The main protective measures against staph and strep are preventing direct hand contact with ready to eat food and refrigerating food.

Viruses from food handlers

Several varieties of viruses are passed between people by the fecal-oral route. They include the enteroviruses, parvoviruses, rotaviruses, small round structured viruses (Norwalk agent, calcivirus, astrovirus), and hepatitis viruses A and E. The typical infection caused by these viruses produces symptoms of nausea, diarrhea, vomiting, fever, and body ache. The hepatitis viruses can also produce jaundice and extreme fatigue. Although most commonly transmitted directly from person to person, these viruses can be transmitted in food contaminated with human fecal matter, especially from the hands of food workers. The viruses cannot multiply in food. It is very difficult and expensive to determine the presence of viruses. No indirect indicator is available to monitor for viruses. The protective measures against transmission through food are thorough handwashing after using the restroom and before handling food. Since people tend not to be diligent about handwashing practices, preventing direct hand contact with ready to eat food may be the most effective protective measure.   Protecting water supplies from human fecal contamination is also an important measure to protect food from contamination.

Protozoa from food handlers

Certain protozoan parasites can be transmitted by the fecal-oral route. They include *Entamoeba histolytica* and *Giardia lamblia*. They cause infections of the gastrointestinal tract which are frequently very long-lasting. There are no indirect indicators for the causative agents in food. The protozoan pathogens do not multiply in food. The protective measures against transmission are thorough handwashing after using the restroom and preventing direct hand contact with ready to eat food.

Bacteria natural to the environment
Several varieties of bacteria that can cause foodborne illness are found in soil, in water, or on vegetation without necessarily being associated with human or animal fecal contamination. They include spore-forming *Bacillus cereus, Clostridium perfringens,* and *Clostridium botulinum.* The spores are not destroyed by normal cooking procedures. At moderate temperatures, the spores can start growing and the bacteria can produce toxins in food. The symptoms the toxins produce include diarrhea from *C. perfringens*; either vomiting or diarrhea from *B. cereus*; and life-threatening paralysis from *C. botulinum*. The toxin produced by *C. perfringens* can be destroyed by reheating food to 165 degrees before serving. The toxins of the other two cannot be reliably destroyed without extreme heating. No indirect indicators exist for these causative agents. The protective measures against the causative agents are refrigeration, hot holding, acidity of food, or use of other bacterial growth inhibitors.

Two other environmental bacteria that can cause food-borne illness are *Listeria monocytogenes* and *Vibrio parahaemolyticus.* The former is found in many environments, including in water and on vegetation. The latter is found in marine water and sediment. They become hazardous when they multiply in nutrient-rich food items. They both produce illness by infection. *L. monocytogenes* can produce serious illness, including septicemia in a pregnant woman that is life-threatening for her fetus. An infection with *V. parahaemolyticus* is usually limited to gastroenteritis. Protective measures against these bacteria include cooking; refrigeration; preventing cross-contamination between raw and cooked foods; and pasteurization of milk (*L. monocytogenes*).

Access to Public Health Protection

Public health protective measures for food are applied to specific settings (e.g. restaurants) that have been targeted by laws and ordinances. Food handling practices are not addressed in other settings. Food handling procedures performed in homes, in small day care settings, at private parties, churches, and in many volunteer food service operations are not reviewed by food protection agencies. It would be impractical and intrusive for government to impose inspections on people in all food preparation settings. Consumer education is an activity of government that might yield significant protection of public health. An inclusion of food safety principles and good handwashing practices in curricula of the public schools might be particularly beneficial. Consumer education activities of state and local Cooperative Extension personnel might be enhanced or augmented by activities of other agencies and by the food industry. Consumer education activities should include culturally sensitive material relevant to all groups of people, including members of various ethnic groups and individuals with increased susceptibility to foodborne illness.

Food protection measures employed by governmental agencies for some segments of regulated settings are meager. For example, food handling activities that are performed at night or on weekends are rarely checked by inspectors. Food transportation is difficult to monitor, usually crosses jurisdictions, and, therefore, is rarely checked. The food industry is relied on to assure that food remains safe. A management technique being promoted by many governmental agencies and industry associations, intended for food companies to use for themselves as a comprehensive protection measure, is called Hazard Analysis [of] Critical Control Point[s] (HACCP). Basically, HACCP is a system for considering potential food handling hazards in advance and implementing measures to prevent and monitor the hazards. Currently, HACCP is mandated for only a few segments of the food industry.

Some public health protection measures are implemented only after an indicator is measured. Without good systems to measure the indicators, the protection measures will not be appropriately applied at appropriate times. A network of federal, state, and local health agencies must be functional and have good links with health care providers and the food industry. Failure of a food worker with hepatitis A to seek medical attention or failure of health care providers to identify and report that worker's illness to public health agencies will prevent recognition of the need for implementing measures to exclude that worker from food handling activities until recovered. Failure of the system to identify an outbreak of cases will prevent recognition of the need to implement extensive consumer advisories or other measures to control the disease in the community.

Food Protection Indicators

Disease/Illness/Injury	Causative Agent/Hazard (Direct Indicator)	Indirect Indicator	Protective Measures
Natural Biological Toxins			
crosis, cirrhosis, neurologic	Mushrooms, plants, ciguatera fish		Expert training on identification & rejection
cancer, etc.	Mold toxins (e.g. aflatoxins)	Spoilage visible	Dry storage, spoilage rejection
ory difficulties, tissue swelling	Histamine (scombroid fish)	Spoilage odor	Temperature control, spoilage rejection
Chemicals			
gic injury, liver necrosis	Pesticides, other organic chemicals	Odors	Approved sources (USDA, FDA, WSDA controls), labeling, approved food containers, water supply protection, education
vomiting, tissue necrosis	Cleaners (e.g. detergents, TSP)		
vomiting, neurologic injury, onormalities	Heavy metals (e.g. Pb, Zn, Cd, Cu, Hg)	Water coloration, flavor	
headache, breathing difficulty	Food additives (e.g. MSG, sulfites)		
Microorganisms			
	Bacteria from animal sources		
teritis, septicemia	*Campylobacter jejuni*	Phosphatase in milk	Milk pasteurization, refrigeration, cooking, vegetable washing, no cross-contamination, water supply protection, reheating before service
	Salmonella spp.		
liarrhea	*Escherichia coli* (enterohemorrhagic strains)		
nal cramps	*Yersinia enterocolitica*		
	Parasites from animal sources		
sis	*Trichinella spiralis*	Meat inspection	Cooking, freezing
l tapeworm infestation	*Taenia saginata (beef), Taenia solium (pork), Diphyllobothrium latum (fish)*	Candling fish fillets	Approved source (USDA) Water supply protection, vegetable washing
l roundworm infestation	*Anisakis spp., Pseudoterranova spp.*		
teritis	*Giardia lamblia, Cryptosporidium spp.*		
smosis, fetal injury	*Toxoplasma gondii*		Cooking Education about hygiene regarding cat feces

Disease/Illness/Injury	Causative Agent/Hazard	Indirect Indicator	Protective Measures
	Bacteria from food handlers		
teritis, septicemia	*Campylobacter jejuni*, *Salmonella* spp.		Hygiene, refrigeration, reheating
teritis, bloody diarrhea	*Escherichia coli*, *Shigella* spp.		
stroenteritis	*Staphylococcus aureus* (toxin)		
stroenteritis	*Streptococcus* Group D (toxin)		
fever	*Salmonella typhi*		
	Vibrio cholerae		
	Viruses from food handlers		
	Hepatitis A, hepatitis E		Hygiene
teritis, fever, chills, body ache	Enteroviruses, parvoviruses, rotaviruses, small round structured viruses (Norwalk virus, calcivirus, astrovirus)		
	Protozoa from food handlers		
teritis	*Entamoeba histolytica*		Hygiene
	Giardia lamblia		
	Bacteria natural to environment (soil, water, vegetation)		
stroenteritis	*Bacillus cereus* (toxin)		Refrigeration, hot holding, reheating, pH control, other bacterial growth inhibition, cooking, no cross-contamination, pasteurizing milk
teritis, abdominal cramps	*Clostridium perfringens* (toxin)		
	Clostridium botulinum (toxin)		
ia, fetal injury	*Listeria monocytogenes*		
teritis	*Vibrio parahaemolyticus*		

On-Site Sewage Indicators

A primary consideration for promoting public health is to assure that on-site systems protect the public from the biological and chemical hazards associated with society's sewage waste stream. Proving direct links to disease due to inadequate on-site sewage management is often difficult in Washington state, yet the failure to provide adequate sewage management is recognized worldwide as a significant public health concern.

Pathways for transmission of disease agents from failing on-site sewage systems include: 1) contaminated drinking water, shellfish areas, and water recreation areas; 2) vectors; and 3) direct contact with contaminated soils or surface waters. Sewage is recognized as a contaminant that must be controlled, rather than as a medium such as drinking water in which contamination must be prevented. When contaminant control measures are required, control is accomplished through containment, isolation and treatment.

Indicators to monitor the environmental status of liquid waste management, including on-site sewage systems, have relied on: system performance standards (e.g. repair permits/total systems); number and percent of homes surveyed for sewage system failures; and number of complaints. Other indicators have been based on measuring pollution impacts on shellfish growing areas, recreational water areas, and other environments.

Indicators

Failing on-site systems can cause the transmission of pathogenic organisms that are responsible for gastrointestinal and other illnesses. Total/fecal coliform testing, which identifies potential fecal contamination of various environmental media, has been historically employed as an indirect indicator of these pathogenic organisms. Therefore, total/fecal coliforms, when detected in media such as drinking water, shellfish growing areas, or water recreation areas, may indicate inadequate or failing on-site sewage systems. In addition to the transmission of organisms from on-site systems, chemicals may be inappropriately disposed in on-site sewage systems, which may then contaminate ground and surface waters (refer to Drinking Water Quality Indicators).

Site conditions can impact safe on-site sewage management practices when monitoring existing systems or when designing and installing new systems. Such conditions include system status, geophysical conditions, and regional socio-economic conditions. Local health jurisdictions focus public health protection efforts on those regions of higher public health concern for safe on-site sewage management. For example, a region in a community that is characterized as having older on-site sewage systems, limited vertical separation to water table, proximity to shellfish growing areas, and low employment rate (homeowners may lack the financial means to correct on-site sewage system problems) would be identified as a "high risk area" for failing on-site sewage systems. Once identified, local health departments could then focus their limited resources on these areas to screen for problems. As described in the protective measures column, various indicators may be selected as appropriate to identify these areas in a community. An additional step would be to plot this information onto a geographic information system (GIS) to highlight areas of local health department priority.

Access to Public Health Protection

Primary efforts of local health departments have traditionally focused on the initial siting and installation of on-site sewage systems. Once a system is installed, it is primarily the responsibility of the property owner to assure that the system continues to function properly. Though regulations require on-site systems to operate in a manner that protects public health, environmental health jurisdictions often do not have the resources to conduct routine compliance monitoring. As a result, failing systems are often only identified through such mechanisms as periodic monitoring, receiving complaints, or the repair permitting process. The adequacy of on-site systems could be further assured if more attention were focused on the maintenance and repair of systems.

On-Site Sewage Indicators

<table>
<tr><th>Illness/Disease/Injury</th><th>Causative Agent/Hazard</th><th>Indirect Indicator</th><th>Protective Measures</th></tr>
<tr><td colspan="3">Bacterial</td><td></td></tr>
<tr><td>Gastroenteritis, diarrhea, cholera, bacillary dysentery, typhoid fever, paratyphoid fever, yersiniosis</td><td>Escherichia coli (enterotoxigenic strains), Vibrio cholerae, Shigella spp., Salmonella spp., Yersinia spp.</td><td>Contamination of drinking water, surface water, water recreational areas, shellfish growing areas, surface soils, and other environments as evidenced by the presence of total and fecal coliform indicators</td><td rowspan="5">Proper siting, design, installation, maintenance, repair and monitoring
Education
Establishing areas at increased risk for system malfunction by using the following:

A) PHYSICAL CONDITIONS (e.g.)
• Coarse soils
• Extremely fine textured soils
• Vertical separation to ground water
• Topography which concentrates rain events
• Unconfined aquifers (for shallow drinking water wells

B) LOCATIONAL CONDITIONS (e.g.)
Horizontal distance to
• Surface water
• Wells (shallow, hand-dug, illegal)
• Water recreational areas
• Shellfish growing areas

C) EXISTING ON-SITE SYSTEMS (e.g.)
• Aging systems
• Undersized systems
• Overloaded systems
• Illegally installed systems</td></tr>
<tr><td colspan="3">Protozoan</td></tr>
<tr><td>Amebiasis (amebic dysentery), balantidiasis (balantidial dysentery), cryptosporidiosis, giardiasis, gastroenteritis</td><td>Entamoeba histolytica, Balantidium coli, Cryptosporidium spp., Giardia lamblia</td><td>No indicators with correlation for cyst forming protozoa</td></tr>
<tr><td colspan="3">Viral</td></tr>
<tr><td>Viral hepatitis A, epidemic viral gastroenteritis, diarrhea</td><td>Hepatitis A, Norwalk virus</td><td>Contamination of drinking water, surface water, water recreational areas, shellfish growing areas, surface soils, and other environments as evidenced by the presence of total and fecal coliform indicators.</td></tr>
</table>

Inorganic, Volatile Organic, and Synthetic Organic Chemicals			• Failing systems
See “Drinking Water Indicators”			D) SOCIOECONOMIC CONDITIONS (e.g.) • Level of income • Level of employment • Availability of other regional resources

Solid Waste Exposure Indicators

A consideration for promoting public health is to assure that systems are in place to protect the public from the physical, biological and chemical hazards associated with society's municipal solid waste (MSW) stream. Proving direct links to disease due to MSW management is often difficult, yet the failure to provide adequate MSW management is recognized as a public health concern.

For the purposes of this discussion, municipal solid waste constitutes waste that can be legally disposed of in a city or county solid waste handling facility. MSW includes waste from residential, commercial, institutional, and some industrial sources that are collected, processed, and disposed through the municipal solid waste handling system. Such waste may include paper (e.g. newspaper, corrugated paper), plastic, glass, ferrous metals (e.g. tin cans, bi-metal cans, mixed metal), non-ferrous metals (e.g. aluminum cans), organics (e.g. food, yard wastes), construction debris (e.g. wood wastes, gypsum), and other waste (e.g. disposable diapers, textiles). In addition, waste may illegally enter the MSW waste stream such as hazardous waste (e.g. paints, solvents, cleaners, pesticides, non-vehicle batteries), or as other special waste (e.g. used oil, vehicle batteries, biomedical wastes).

The MSW stream may be viewed as a "stew" of physical, chemical and biological agents generated by the human population. As such, human occupational exposure to physical, chemical, and biological hazards associated with the MSW stream may directly occur during the collection, processing, treatment, or disposal phases of municipal solid waste handling. Because MSW is managed in a largely confined system, direct exposure by the general population to hazardous agents in MSW is minimal. However, the general population may be indirectly exposed to potentially hazardous chemical or biological agents if released to the environment through air, surface or ground water, or through vectors of infectious disease. Though Washington State has an extensive regulatory system in place to prevent such releases from solid waste handling facilities, such events may still occur.

Indicators

Environmental health indicators are presented in the adjoining table for 1) solid waste collection, 2) transfer stations, 3) landfills, 4) moderate risk waste facilities, 5) compost and recycling/sorting facilities, and 6) waste-to-energy (incineration) facilities. For each, indicators of direct exposure to physical, chemical, or biological hazards are primarily limited to occupational exposures for MSW handled under the current state and local solid waste regulatory system. However, illegally disposed waste (e.g. used hypodermic needles), can also present a direct exposure hazard to the general population. Indirect indicators for solid waste exposure are primarily ground water monitoring, air sampling and records of occupational illness and injury. The MSW protective measures rely largely on systems to measure the success of meeting state and local regulations for solid waste, air quality, water quality, dangerous waste, and occupational safety.

Because improperly managed MSW represents an environmental contaminant, the four column environmental indicators model presented here relies on other indicator models found in this document to properly assess disease, illness or injury in communities. The sections on other environmental indicators are: 1) Ambient Air Quality, 2) Drinking Water, 3) Water Recreation, 4) Zoonotic Disease, and 5) Hazardous Waste Exposure.

Access to Public Health Protections

Public health protective measures for MSW are implemented to minimize the release of physical, chemical, or biological hazards to the environment. With the promulgation of MSW landfill standards by the U.S. Environmental Protection Agency in 1991, and the subsequent adoption of those standards by the Washington State Department of Ecology, the costs associated with operating MSW landfills, and of operating a solid waste management system in general has greatly increased. It is suspected that increased costs could lead to an increase in illegally disposed MSW, particularly in rural areas of the state.

Solid Waste Indicators

Disease/Illness/Injury	Causative Agent/Hazard	Indirect Indicator	Protective Measures
Solid Waste Storage/Collection			
Physical injury (e.g. cuts, scratches, scrapes, punctures, etc.)	Improperly or unsafely contained or stored solid waste	Occupational injury records/statistics	Worker protective gear Occupational safety precautions Proper solid waste disposal
Needlestick injuries	Uncontained hypodermic needles	Number of intravenous drug users Occupational injury records/statistics	Proper hypodermic needle disposal Education
Transfer Stations			
Occupational pulmonary disorders, gastrointestinal problems among transfer station employees Also, see “Ambient Air Quality Indicators”	High ambient concentrations of airborne: • dust; • bacteria; • fungal spores; • toxic organic chemicals inorganic chemicals	Occupational injury, illness records/statistics Air sampling information	Worker respiratory safety equipment Worker education
See “Drinking Water Indicators” See “Water Recreation Indicators”	Toxic organic chemicals and inorganic chemicals; pathogenic microbial contaminants in leachates migrating off-site		Surface water run-off controls
Landfills (Municipal Solid Waste, Woodwaste, Construction/Demolition Waste, Industrial Waste Landfills)			
Occupational pulmonary disorders, gastrointestinal problems among landfill employees Also, see “Ambient Air Quality Indicators”	h ambient concentrations of airborne: • dust; • bacteria (e.g. fecal coliform bacteria); • fungal spores; • toxic organic chemicals, inorganic chemicals	Occupational injury/illness records/statistics Air sampling information	Worker respiratory safety equipment Worker education
See “Drinking Water Indicators” See “Water Recreation Indicators”	Toxic organic chemicals, inorganic chemicals, pathogenic microbial contaminants in leachates	Ground water monitoring	Leachate collection systems Surface water run-off controls
See “Zoonotic Disease Indicators”	Pathogenic microorganisms		Bird control Daily cover of the landfill face

Disease/Illness/Injury	Causative Agent/Hazard	Indirect Indicator	Protective Measures
Moderate Risk Waste Facilities			
See "Hazardous Waste Exposure Indicators"	Toxic organic chemicals, inorganic chemicals	Occupational injury; illness records/statistics Air sampling information	Worker protective gear Worker safety precautions Worker respiratory safety equipment
Compost and Recycling/Sorting Facilities			
Occupational Gastrointestinal problems (e.g. nausea, diarrhea) Occupational irritation of the skin, eye and mucous membranes of the nose and upper airways Occupational pulmonary diseases (e.g. asthma, alveolitis, bronchitis Occupational organic dust toxic syndrome (cough, chest-tightness, dyspnoea, influenza-like symptoms such as chills, fever, muscle ache, joint pain, fatigue and headache)	High ambient concentrations of airborne • dust; • bacteria; • fungal spores; • toxic organic chemicals, inorganic chemicals	Occupational injury, illness records/statistics Air sampling information	Worker respiratory safety equipment
See "Drinking Water Indicators" See "Water Recreation Indicators"	Toxic organic, inorganic chemicals; pathogenic microbial contaminants in leachates	Ground water monitoring	Surface water run-off controls Ground water run-off controls
Waste to Energy (Incineration) Facilities			
Occupational pulmonary disorders, gastrointestinal problems See "Ambient Air Quality Indicators"	High concentrations of airborne: • dust; • bacteria; • fungal spores; • toxic organic chemicals, inorganic chemicals	Occupational injury/illness records/statistics Morbidity statistics	Worker safety precautions

Water Recreation Protection Indicators

Water recreation presents health hazards from physical injury, exposure to toxic chemical agents, and transmission of infectious disease. Approximately ten million person-visits to recreational bodies of water occur each year in Washington. Recreational waters can be divided into two categories: natural (marine waters, lakes, streams) and artificial (pools, spas, water slides). There are both similar and different agents of disease, illness, or injury associated with the two water recreation categories.

Physical Injury

Drowning, near-drowning, and traumatic injuries are dramatic adverse health conditions associated with water recreation. The causes of the conditions are direct indicators of the hazards. Such causes include lack of swimming skill, tiredness, boating accidents, diving accidents, falling/slipping/tripping, horseplay, and entrapment. Water conditions are indirect environmental indicators of the activities which cause the adverse health conditions. Such water conditions include rip-tides and other fast moving water conditions for natural water bodies and visibility through the water for artificial water bodies. Protective measures for both types of water bodies include lifeguards on duty, lifeguard training, safe design, and public education about safe swimming practices. An additional protective measure for natural water bodies is the posting of warning signs for unsafe water conditions.

Water temperature can cause physical injury. Cold water immersion can cause hypothermia, a decrease in body temperature. Hot water immersion can cause hyperthermia, an increase in body temperature. Either condition can be life-threatening. Water temperature combined with the duration of exposure are the direct indicators of the environmental agent which causes the injury. Water temperature alone is an indirect environmental indicator. Public education about the risks of exposure to cold/hot water and about the increased risk when substance abuse is involved is a protective measure for this hazard.

Chemical Injury

Chemical burns of the eyes, skin, or respiratory passages can be caused by chemicals used to treat artificial water bodies. Exposure to the chemicals can occur by means of contact with the recreational water or by inhalation of toxic gasses in the area. The agents most commonly involved are hypochlorous acid in the water and chlorine gas released into the air in enclosed pool/spa facilities. Indirect indicators of the hazardous agents include tests for disinfectant level and pH level. The main protective measure for these agents is operator training.

Chemical toxicity can also be caused by ingestion of algal toxins (e.g. *Anabaena* toxin) from natural water bodies. The toxin levels in the recreational water are direct indicators of the disease agent in the environment. The concentration of specific algae in the water is the indirect indicator. The main protective measures are public warnings (e.g. posting beaches, news alerts) when conditions are hazardous.

Infectious Disease Transmission

Infectious disease can be transmitted in water recreation situations by either skin contact with the water; skin contact with pool or spa surfaces; ingestion of some of the water; or inhalation of aerosols from the water. Disease transmission can also occur directly from person to person because of crowding. The illnesses that can result from skin contact with recreational waters or associated facilities include mild skin irritation (swimmer's itch), skin inflammation, urinary tract infection, ear infection, and eye infection. The disease agents most commonly acquired by skin contact are bacteria (e.g. *Pseudomonas*), parasites (e.g. *Schistosoma*), and fungi (e.g. *Mycobacterium*). Viruses (e.g. adenoviruses) can cause eye infections through transmission in recreational waters. Various types of illnesses can result from the ingestion of recreational waters containing bacteria (e.g. *E. coli* 0157:H7), viruses (e.g. Norwalk), or parasites (e.g. *Giardia*). The illnesses can range from mild gastrointestinal upset to severe liver damage. Respiratory tract infections can result from the inhalation of aerosolized recreational waters containing bacteria (e.g. *Legionella*), viruses (e.g. adenoviruses), or fungi (e.g. *Aspergillus*).

Potential exposure to infectious agents differs between natural water bodies and artificial ones. Natural water bodies are subject to pollution with animal as well as human waste. They can serve as habitat for many kinds of animals, which can harbor the life cycles of parasites (e.g. schistosomes). They are also more likely to have a greater variety of natural microorganisms with the potential to cause illness. They are difficult or impossible to effectively treat with disinfectants. They can have some advantages over artificial water bodies due to dilution of pathogens contributed by the people using the water for recreation. Artificial ones must be properly treated to prevent pathogens from the users being in high concentration. Pathogens are washed off of the surface of bathers. Pathogens can also be contributed by fecal material from the bathers, especially young children. Pathogens from the skin (e.g. *Mycobacterium*) are more likely to be a problem at water recreation facilities (by direct contact with artificial surfaces) than at natural bathing beaches.

Useful indirect indicators of infectious agents in natural water bodies include measurements of the Most Probable Number (MPN) concentration of fecal coliform bacteria, generic *E. coli* strains, or *Enterococcus* bacteria; sanitary survey of the watershed; and waterfowl usage of the water. Washington state has not adopted any standards for bacterial MPN in natural bathing waters. Useful indirect indicators of infectious agents in artificial water bodies include disinfectant level, total dissolved solids level, total coliform bacteria MPN, and total bacterial concentration (heterotrophic plate count method). Protective measures for natural bathing beaches include public education and warnings (e.g. posting beach, news alert, informational flyers) about potential hazards. Protective measures for artificial water recreation facilities include operator training (e.g. disinfection, filtration, water replacement) and public education (e.g. warning about effects of infants in diapers, warning to immunocompromised people about their susceptibility to certain diseases).

Access to Public Health Protection

Public health agencies do not conduct or monitor protective measures for many types of water recreation areas, especially natural water bodies. Users of public natural bathing beaches may be provided some protections, depending on the local jurisdiction. Users of natural water bodies that are not designated public bathing areas are not provided protection. Users of public artificial water recreation facilities are provided the most protection. Users of public natural bathing areas or public artificial facilities are provided protection through regulation if the number and type of users fit regulatory categories. Regulations for public facilities specify when lifeguards are required, training required for lifeguards, design criteria, and operation criteria. Owners of natural bathing beaches or private artificial facilities are not provided public health protection. Users of shared artificial facilities at apartment or condominium complexes are provided public health protection only if the pool or spa serves enough units to meet a regulatory threshold.

Water Recreation Protection Indicators

Disease/Illness/Injury	Causative Agent/Hazard (Direct Indicator)	Indirect Indicator	Protective Measures
Natural Water Bodies			
Drowning, near drowning, injury (major/minor)	Lack of swimming skill, tiredness, boating accident, diving accident, falling/slipping/tripping, horseplay, entrapment	Water conditions (e.g. riptide, fast moving water)	Parental/guardian supervision Lifeguard on duty, lifeguard training Safe design of developed beach Posted warnings Public education (e.g. swimming training, use of personal floatation devices, dangers of alcohol/drugs, dangers of risk taking, dangers of swimming alone)
Hypothermia	Cold water/duration	Water temperature	Public education
Gastroenteritis, shigellosis, hepatitis	Bacteria (e.g. *Shigella*, *E. coli* 0157:H7) Viruses (e.g. enteroviruses, Norwalk, hepatitis A) Parasites (e.g. *Giardia*, *Cryptosporidium*)	Fecal coliform MPN, *E. coli* MPN, *Enterococcus* MPN Sanitary survey	Public warnings (e.g. posting beach, news alert)
Respiratory tract infection	Bacteria (e.g. *Pseudomonas*, *Legionella*) Viruses (e.g. adenoviruses, rhinoviruses)		
Neurologic damage, liver damage	Biotoxins	Blue-green algae levels (e.g. *Anabaena*, *Microcystis*)	Public warnings (e.g. posting beach, news alert)
Skin irritation (swimmer's itch)	Schistosomes	Waterfowl	Education (e.g. toweling, showering)
Artificial Water Bodies			
Drowning, near drowning, injury (major/minor)	Lack of swimming skill, tiredness, diving accident, falling/slipping/tripping, horseplay, entrapment	Visibility through water	Parental/guardian supervision Lifeguard on duty, lifeguard training Safe design, fencing Public education (e.g. swimming training,

			dangers of alcohol/drugs, dangers of risk taking, dangers of swimming alone)
Hyperthermia, fetal injury	Hot water/duration	Water temperature	Public education (e.g. dangers of alcohol/drugs)
Chemical burn	Hypochlorous acid, chlorine gas	Disinfectant level in water, pH	Operator training

Disease/Illness/Injury	Causative Agent/Hazard (Direct Indicator)	Indirect Indicator	Protective Measures
Gastroenteritis, shigellosis, hepatitis	Bacteria (e.g. *Shigella*, *Salmonella*) Viruses (e.g. enteroviruses, Norwalk, hepatitis A) Parasites (e.g. *Giardia, Cryptosporidium*)	Disinfectant levels Total dissolved solids Total coliform MPN Heterotrophic plate count	Operator training (e.g. disinfection, filtration, water replacement) Public education (e.g. warning about effects of infants in diapers, warning to immunocompromised)
Skin infection	Bacteria (e.g. *Pseudomonas, Mycobacteria, Staphylococcus)*		
Urinary/genital tract infection	Bacteria (e.g. *Pseudomonas*) Yeasts		
Respiratory tract infection	Bacteria (e.g. *Pseudomonas*, *Legionella*) Viruses (e.g. adenoviruses, rhinoviruses) Molds		
Ear infection	Bacteria (e.g. *Pseudomonas*)		
Meningoencephalitis, eye infections	Parasites (e.g. *Naeglaria*, A*canthamoeba)* Viruses (e.g. adenoviruses)		

Hazardous Waste Exposure Indicators

There are toxic materials in almost every part of daily living. In most communities, there are numerous sources of potential environmental contamination, such as hazardous waste sites, manufacturing facilities, illegal drug labs, dry cleaners, and other retail businesses. The fuels and lubricants in cars, the cleaning fluids in homes, and the chemicals in copy machines and printers in the work environment are all toxic. Any toxic material may be a hazardous waste depending on the circumstances. For example, a pesticide properly mixed and applied to a crop is not a hazardous waste. However, if the same pesticide is spilled on the road during an accident, it is a hazardous waste. A bottle of benzene sitting on a shelf in a chemical processing plant is toxic but not a hazardous waste. If the benzene is used in a manufacturing process, and becomes diluted or contaminated and is stored while waiting disposal, it is a hazardous waste. In general, any toxic material that is released outside its range of normal and safe use, or is contained and awaiting disposal, can be considered a hazardous waste. Environmental health professionals are obviously most concerned with hazardous waste that has been released in an uncontrolled manner and is contaminating an environmental pathway that can lead to human disease, illness or injury.

Direct indicators, indirect indicators, and protective measures have been established for hazardous waste exposures, that highly correlate with difficult to measure adverse health effects. In choosing a hazardous waste indicator, if the hazardous material is released into the water or air, appropriate indicators might also be found in other sections of this document (Ambient Air Quality, Drinking Water Quality, Pesticide Exposure, and Indoor Air Quality).

Direct and Indirect Indicators

Chlorinated pesticides
See Pesticide Exposure Indicators.

Polychlorinated biphenyls (PCBs)
There are over 200 PCBs with varying adverse health effects. Although PCBs are no longer manufactured in the United States, transformers and other devices which contain PCBs are still in use. Several hazardous waste sites in Washington are contaminated with PCBs. People living near these sites may be exposed via air releases. Children might be exposed by contact with contaminated soil. Consumption of fish contaminated with PCBs is another way people may be exposed. Health effects vary depending on the route of exposure, individual susceptibility as well as the extent of exposure. Adverse effects include liver damage, reproductive effects, skin irritation (chloracne) and cancer. The indirect indicator for PCBs is the detection of the specific PCB or related compounds in a chemical screen.

Volatile organic chemicals (VOCs)
See Drinking Water Quality Indicators and Indoor Air Quality Indicators

Polyaromatic hydrocarbons (PAHs)
PAHs are a group of chemicals that are formed during the incomplete combustion of coal, oil, gas, wood, garbage and other organic compounds. There are over 100 different PAHs and they usually occur in complex mixtures and can be found in crude oil, coal, creosote, and roofing tar. The primary source of exposure to most of the population is through inhalation of the compounds in tobacco smoke, wood smoke, ambient air, and the consumption of certain foods. The primary adverse health effects include liver function problems and cancer. The indirect indicator for PAHs is the identification of any PAH in a chemical screen.

Heavy metals
Lead and its deleterious effects on children have gained national prominence during the past few years. Elevated blood lead in young children can have adverse effects that might not become apparent until years after the exposure. Demonstration of lead in the paint, dust, or soils around a home may be used as a direct indicator of elevated blood lead in children. In the absence of direct lab measures, any home built prior to 1976 probably contains leaded paint, and hence the percentage of homes in a community built prior to 1976 may be used as an indirect indicator. Also, see Drinking Water Quality Indicators.

PM10, fibers
See Ambient Air Quality Indicators.

Nitrates
See Drinking Water Quality Indicators.

Dioxins
The terms "dioxins" or "dioxin-like" compounds refers to 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) and other structurally related chemicals. Dioxins have been extensively studied over the last two decades, and their presence in our environment represents an important issue of public health significance. Dioxins are highly persistent, tend to strongly adsorb to particulate matter, circulate between environmental media (air, water, and soil) through various transport mechanisms, and biomagnify in animal species. Chloracne, a disfiguring skin disease, has been definitively associated with exposure to TCDD in humans. Additionally, some epidemiological evidence suggests that exposure to TCDD and related chemicals may increase the incidence of some forms of cancer. The indirect indicator for dioxins is the presence of uncontrolled point source pollution sites.

Illegal drug lab materials
The illegal manufacture of drugs has become a significant public health problem in Washington State during the past few years. The manufacturing process requires a large number of chemicals with a wide range of adverse health effects. The greatest danger is to the occupants of the illegal drug lab building. When the illegal lab is discovered, law enforcement and health department personnel may be exposed to toxic materials unless they are fully trained in the appropriate use of personal protective equipment. Effects from exposure to illegal drug lab contaminants include gastrointestinal effects, mucous membrane irritation of eyes, nose, and lungs, skin irritation, central nervous system effects, and carcinogenesis. The indirect indicator for these materials is the presence of an illegal drug lab.

Irritants
See Ambient Air Quality Indicators.

Protective Measures

Public health activities that identify hazardous waste sources, document completed pathways, and take the appropriate actions, provide the protective measures for all hazardous waste exposure indicators discussed. For all indicators provided, protection can be any action that breaks the exposure pathway. The intervention can range from providing an alternate drinking water source, issuing a health advisory on consumption of fish or other food products, restricting access to a site, or something as complex as a full site remediation. Education can also be an important activity in breaking the exposure pathway. By educating communities on how to avoid an exposure, the pathway is effectively broken. For example, educating parents on reducing exposure to lead in contaminated homes is an effective intervention to prevent elevated blood lead in children. Education of community health-care providers, and decision makers can also assist in proper medical care and expedited cleanup activities. Education and community involvement are perhaps the best method to aid in the relief of psychological stress and stress-related illness associated with hazardous waste sites or an uncontrolled contaminant release.

Access To Public Health Protection

There is a lack of routine testing for hazardous waste in many areas such as light industrial and mixed use communities. Communities in close proximity to industrial areas often have exposures to hazardous waste that go unnoticed, and they may be at increased risk. When a hazardous waste site is discovered, months and sometimes years may pass before the site is fully cleaned. While the lengthy remediation efforts proceed, community exposure may continue. Another issue nationally, is the accusation of environmental inequity. The basis for this is the belief that certain populations bear a greater environmental burden than others. Some populations appear to be under served by environmental cleanup agencies. There is some evidence that not all populations are treated with equal regard, and certain areas may be cleaned up faster and to lower contaminant levels than others.

Psychological stress and stress-related illness caused by the uncertainty of exposure to contaminant release is a major new area of investigation. Several national efforts are looking at the causes, evaluation methods, and intervention strategies to address this area. It has been found that living in a community near a hazardous waste site, even in the absence of any data to show true hazardous material exposure, can result in stress related adverse health effects in the residents. The best way to address these stress related adverse effects is to acknowledge the community concern, and provide education as to the true risks in the community. Psychological stress and stress-related illness has not been widely recognized in the past, and those suffering from this effect are probably under served.

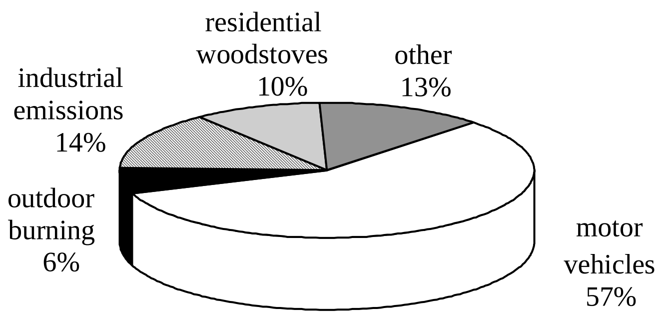
Hazardous Waste Indicators

Disease/Illness/ Injury	Causative Agent (Direct Indicator)	Indirect Indicator	Protective Measures
Liver, reproductive, skin effects, cancer	PCBs, chlorinated pesticides	Identification of any PCB or chlorinated pesticide in a chemical screen	Exposure pathway interruption activities. (e.g. site remediation, community health education, health professional education, resident relocation, alternate water supplies)
Nervous system and kidney effects, cancer	VOCs (e.g. TCE)	Identification of any VOC in a chemical screen	
Liver effects, cancer	PAHs	Identification of any PAH in a chemical screen	
Skin, reproductive, developmental effects, cancer	Heavy metals (e.g. arsenic, lead)	Homes build before 1976 (Pb), illegal drug labs, old orchards	
Lung effects	PM10, fibers	Regional haze, decreased visibility, see “Ambient Air Quality Indicators”	
Developmental effects, methemoglobinemia	Nitrates	Widespread fertilizer applications, failing septic systems	
Liver, reproductive, skin effects, cancer	Dioxins	Uncontrolled hazardous waste sites, or other uncontrolled sources	
Gastrointestinal effects	Tartaric acid	Illegal drug labs	
Mucous membrane irritation	Ammonium acetate, ammonium fornate, cuprous oxide, tartaric acid		
Physical injury	Hydrazine and lithium aluminum hydride (explosives)		
Eye, skin, lung effects	Irritants, (e.g. iodine, acid fumes, other VOCs)		

Ambient Air Quality Indicators

Air pollution is a major public health concern because inhalation of air pollution is the route of exposure over which people have the least choice. Air quality in Washington is primarily impacted by local sources and not by long-range transport from out of state. Significant sources of air pollutants within the state include industries, wood stoves, and motor vehicles. The Washington State Department of Ecology has estimated that 57% of air pollution in the state is attributable to motor vehicles (see figure below). Factors such as frequent temperature inversions (weather condition in which warm air is trapped close to the ground) and hilly terrain contribute to localized build-up of air pollutants in some areas.

Sources of Air Pollution in Washington State



source: Washington State Department of Ecology, 1995, Air Emissions Inventory Data, 1994-1995

Direct and Indirect Indicators

Criteria pollutants

Under the Federal Clean Air Act of 1970, the Environmental Protection Agency (EPA) established National Ambient Air Quality Standards (NAAQS) for six air pollutants. These standards are in the form of concentrations allowable in the outdoor air. These six pollutants, commonly referred to as the Criteria Pollutants (see table below), are particulate matter, ozone (ground level), carbon monoxide, nitrogen dioxide, sulfur dioxide, and lead. National air pollution regulations were set for these six pollutants because they are considered ubiquitous and thereby capable of being regulated by a nationally applicable standard. Primary NAAQS standards are set to protect human health, while secondary standards are protective of environmental effects (damage to property, plants, reduction in visibility, etc.).

Criteria Pollutants and their Major Sources

Criteria Pollutant	Major Sources
Particulate matter	Wood stoves, dust, open burning, forest fires, mobile sources[a] (diesel), industry, construction
Ozone	Mobile sources[a], power plants, gasoline storage and transfer, industry, paints, solvents
Sulfur dioxide	Fossil fueled power plants, non-ferrous smelters, kraft pulp production
Nitrogen dioxide	Fossil fueled power plants, mobile sources[a], industry, explosives manufacturing and fertilizer manufacturing
Lead	Leaded gas, smelting, battery manufacturing and recycling, municipal waste combustors (older)
Carbon Monoxide	Wood stoves, open burning, mobile sources[a], industrial combustion

[a]mobile sources refers to cars, trucks, buses, etc.

Particulate matter. Particulate matter (PM) air pollution encompasses several types of particles with different chemical compositions. $PM_{2.5}$ (particulate matter ≤ 2.5 microns in diameter) are attributed to combustion sources, while larger sized particles (between $PM_{2.5}$ and PM_{10}) are attributed to wind-blown dust and other abrasive sources. Particles emitted directly from a source (primary particles) generally consist of a central carbon core upon which other pollutants can be attached, such as polyaromatic hydrocarbons (PAHs) or metals, depending on the source. Additionally, secondary particles can form from constituents in the atmosphere under certain conditions and can include aggregates of sulfur oxides (SOx), nitrogen oxides (NOx), and hydrocarbons.

Recent epidemiological studies indicate that particulate matter air pollution is associated with increases in mortality, especially in people with existing cardiopulmonary disease and infants. These studies have also associated particulate matter air pollution with health effects such as aggravation of asthma, other chronic lung diseases, and increased susceptibility to infectious illnesses.

Ozone. Ozone is the major component of smog. Ambient ozone is not directly emitted from sources but is formed in the environment by reactions involving volatile organic compounds (VOCs) and nitrogen oxides (NOx) in the presence of ultra-violet (UV) sunlight. Ozone is a respiratory tract irritant and has been associated with premature aging of the lung, increases in respiratory tract infections, and aggravating asthma.

Carbon monoxide (CO). Carbon monoxide is formed during combustion. Carbon monoxide impairs the blood’s oxygen carrying ability. Individuals with ischemic heart disease are particularly sensitive to carbon monoxide exposures.

Nitrogen dioxide (NO_2). Nitrogen oxides (NO_x), including nitrogen dioxide, are formed during high temperature combustion by the combination of nitrogen and oxygen in air. Exposure to nitrogen oxides is associated with respiratory tract irritation, affects mechanical defenses of the lung, and suppresses immune response. The NO_x also contribute to ozone formation.

Sulfur dioxide (SO_2). Sulfur dioxide is associated with upper respiratory tract irritation except when in concert with particles, then it is a lower respiratory tract irritant. Young asthmatics are most sensitive to short duration low level exposures (<1ppm).

Lead. Air emissions of lead have decreased significantly since the phasing out of leaded gasoline. Exposure to lead is associated with neurodevelopmental effects in children and with cardiovascular effects in adults.

Hazardous air pollutants (HAPs)
Under the 1990 amendments to the Federal Clean Air Act, the EPA identified 189 pollutants categorized as "hazardous air pollutants" (HAPs, also referred to as Air Toxics). HAPs include organic chemicals, minerals, various metals and metal compounds, and pesticides. Many of these pollutants are associated with chronic health effects including cancer, as well as effects on the respiratory system and other systems. Unlike the Criteria Pollutants, HAPs are attributed to local sources which must be individually addressed by state and local air pollution authorities. The Washington State Department of Ecology identified a total of 468 HAPs for Washington State, which include the 189 federal air pollutants.

One source of air pollution emission information is the Toxic Release Inventory (TRI), which tracks industrial releases of chemicals (either as part of routine operations or by accident). This program is maintained by the EPA. In Washington State during 1995, 90.6% of the reported releases were to air. TRI data are useful indirect indicators for HAPs since they aid in identifying the primary pollutants released from point sources, for identifying the major industrial air pollution sources, and for observing any changes in releases over time.

Radiation
Examples of sources of radioactive air emissions include federal facilities (e.g. Department of Energy facilities), nuclear power plants, and low and high level radioactive wastes. Sources of radiation air pollution are regulated under the Federal Clean Air Act. Also, see Radiation Protection Indicators.

Microorganisms
Microorganisms may be aerosolized from composting, sewage treatment, landfill operations, and sludge biodegradation. Microorganisms from these sources can include bacteria and molds. Microorganisms from these sources can result in allergic illness or infections at high levels of exposure or at lower levels in immunocompromised individuals. Microorganisms can produce toxic gases and odors when grown in an anaerobic (without oxygen) environment.

Odors
Common sources of odors include industrial chemical processes and emissions, composting, and sewage treatment. For example, two odorous compounds, hydrogen sulfide and mercaptans are by-products of anaerobic microbial degradation, which can occur in organic waste ponds. Odors can elicit health impacts such as headaches, nausea, and vomiting which may occur independently of toxicological effects.

Protective Measures

Prevention of adverse health impacts from air pollution is primarily achieved through controlling air pollution at its many sources and by monitoring air pollution levels of some pollutants to ensure that source control measures are working. Operational controls are the primary protective measures for air quality. For Criteria Pollutants, the protective measures include complying with the NAAQS health based standards which allow certain concentrations of these pollutants in ambient air. For HAPs, the protective measures include regulating emissions at their sources by specifying that sources use maximum available control technologies (e.g. stack scrubbers) to minimize emissions. The type of control technologies used at a source must be at least as good as the better control technologies being used at comparable facilities or sources. The protective measures for microorganisms consist of activities such as dust control measures at landfills and composting facilities. Protective measures for odors include local nuisance odor regulations. Usually when odor complaints are registered, the air pollution episode triggering the complaint is not in violation of air pollution regulations. However, in some cases, agencies work with industries responsible for odor episodes to reduce emissions under non-regulatory programs (i.e. pollution prevention). Since practices of individuals can significantly impact air quality (e.g. motor vehicle use, outdoor burning, wood stove use, etc.) air pollution reduction programs often include a public education component as a means of reducing emissions from these types of sources.

In the absence of air monitoring data, air pollution modeling can be used to provide information for estimating exposures. Modeling predicts air pollution levels in an area or region. Modeling relies on computer run programs which are based on the principles of air pollutant behavior in the environment. Information on the amount and types of pollutants released by a source or sources (emission estimates), and meteorological parameters are incorporated into modeling.

Modeling has advantages over monitoring including; it is often less expensive than monitoring, it can provide air concentration information for many pollutants, it can be conducted for a wide geographic area, and it can provide data over extended periods of time. A disadvantage of modeling is that its predictions can be very uncertain depending on how well the model fits the situation under investigation and the appropriateness of data put into the model. However, if conservative assumptions are used, modeling is frequently a good tool for predicting worst case air concentrations which can be used to screen out non-hazardous from potentially hazardous situations.

Access to Public Health Protection

People can be exposed to high levels of air pollution locally even though regional air pollution standards are not violated. Unhealthy levels of air pollution can accumulate in localized areas due to the combined effects of multiple sources or under certain meteorological conditions. The amount and nature of air pollution depends on the types of sources in an area, patterns of pollutant discharges from sources, the topography of the area, and meteorological conditions. In situations where air pollution may reach or is reaching unhealthy levels, health agencies work with air pollution regulatory agencies to evaluate air quality and to reduce air pollution to protect public health.

People in a community can be exposed differently to air pollutants and their exposures can vary throughout the day. An individual's exposure to air pollution depends on personal behaviors including time spent outdoors (although many pollutants can travel indoors), physical activity levels when outdoors, and where a person lives, works and recreates. In addition, people in a community can have varying sensitivities to air pollution depending on age and health status.

Criteria Pollutant regulations are based on health effects information about each pollutant and are set to be protective of sensitive subpopulations such as children, the elderly, and people with existing illness. Because HAPs regulations are control technology based, possible health impacts are not accounted for explicitly in the regulations. Under the Federal Clean Air Act, human health risks associated with HAPs air emissions, that remain after appropriate control technologies have been put in place, will be evaluated. In the meantime, situations may arise where HAPs emissions are being inadequately controlled.

People are usually exposed to air pollution mixtures and not individual pollutants. Air pollution standards are generally aimed at regulating individual air pollutants (NAAQS) although control technology based regulations tend to control mixtures. Evaluating and protecting against health impacts related to exposures to air pollutant mixtures is difficult due to the lack of toxicity information about mixtures and the lack of air monitoring data for mixtures.

Monitoring of pollutants in air provides information for assessing exposures and possible health impacts provided monitors are located in areas where people may be exposed. The time intervals of air monitoring data collection may be critical for evaluating potential health impacts. For example, air monitoring data are frequently collected and averaged over a time period, e.g. a day or year. While this may be appropriate for evaluating chronic exposures, this type of monitoring excludes peak concentrations which may be important if short-term high levels (acute) exposures are of concern.

Ambient Air Quality Indicators

Disease/Illness/Injury	Causative Agent/Hazard (Direct Indicator)	Indirect Indicator	Protective Measures
EPA Criteria Pollutants National Ambient Air Quality Standards (NAAQS)			
Mortality (people with existing cardiovascular disease, elderly, children), aggravation of asthma and bronchitis, ↓ lung function.	PM_{10} (particulate matter less than 10 microns in diameter)	Regional haze/↓ visibility smog temperature inversions ↑ ER and physician visits ↑ medication use loss of work/school days	Compliance with NAAQS and air operating permits, public education, regional burn bans, vehicle emission check programs, ↓ diesel fleets, ↑ carpooling, ↑ regional public transportation, air pollution modeling
Respiratory tract irritation, decrements in lung function (children), premature aging of lung, aggravates asthma, ↓ respiratory defenses against infection.	Ozone (O_3)	Volatile organic compounds (VOCs) nitrogen oxides (NO, NO_2, NO_3, N_2O, N_2O_3, N_2O_4, and N_2O_5) smog warm temperatures/UV sunlight regional haze/↓ visibility ↑ in respiratory tract infections	Compliance with NAAQS and air operating permits, vehicle emission check programs, public education, ↓ diesel fleets, ↑ regional public transportation, ↑ carpooling, gas vapor controls at gas stations, air pollution modeling
Respiratory tract irritation, elicits asthma attacks, bronchitis, wheezing.	Sulfur dioxide (SO_2)	PM_{10} regional haze/↓ visibility, temp. inversions, acid rain (alpine lakes)	Compliance with NAAQS and air operating permits, air pollution modeling
Respiratory tract irritation, aggravates asthma, ↓ respiratory defenses against infection.	Nitrogen dioxide (NO_2)	PM_{10} ozone regional haze/↓ visibility ↑ in respiratory tract infections	Compliance with NAAQS and air operating permits, ↓ diesel fleets, ↑ carpooling, ↑ regional public transportation, air pollution modeling
Neurodevelopmental effects (children)	Lead	PM_{10}	Compliance with NAAQS and air operating permits, banning of leaded gasoline, air pollution modeling
Aggravation of chronic heart disease, elicits ischemia (heart patients).	Carbon monoxide (CO)	Temperature inversions	Compliance with NAAQS and air operating permits, public education, regional burn bans, vehicle emission check programs, air pollution modeling

Disease/Illness/Injury	Causative Agent/Hazard (Direct Indicator)	Indirect Indicator	Protective Measures (source of agent)
Hazardous Air Pollutants 189 pollutants (EPA) 468 pollutants (Dept. of Ecology)			
Cancer and noncancer health effects	Hazardous Air Pollutants (HAPs)	Presence of pollution source categories (e.g. aluminum smelters, drycleaners, etc.), occurance of TRI emissions	Compliance with air operating permits (existing sources), compliance with new source permitting, air pollution modeling
Radiation			
Cancer, acute radiation effects, burns	Radionuclides	Presence of low and high level waste, presence of federal facilities Alpha, beta, gamma radiation	Compliance with air operating permits, air pollution modeling see "Radiation Protection Indicators"
Microbial			
Infections (especially in immunocompromised), allergic illness (asthmatics, immunocompromised), fungal toxicosis, respiratory/neurological effects	Mold spores bacteria microbial by-products (e.g. hydrogen sulfide/mercaptans)	Presence of: compost facilities, landfills, dairy farms, sewage treatment plants, pulp mill sludge ponds, odor complaints, land application of sewage sludge	Compliance with local operating permits (LHDs or other local jurisdictions), control of dust and anaerobiosis
Odors			
Headaches, nausea, vomiting	Chemicals	Odor complaints, presence of pollution source categories (e.g. styrene from fiberglass manufacturing; hydrogen sulfide and mercaptans from pulp and paper industry)	Nuisance odor regulations and control control of anaerobiosis, pollution prevention
Headaches, nausea, vomiting	Microbial by-products (e.g. hydrogen sulfide)	Odor complaints, presence of compost facilities, landfills, sewage treatment plants, pulp mill sludge, dairy farms	Nuisance odor regulations and control of dust and anaerobiosis

Indoor Air Indicators

We spend approximately 90% of our time indoors breathing air that can be more polluted than outdoor air. Poor indoor air quality (IAQ) has been associated with health problems ranging from upper respiratory irritation and chronic disease to death, especially in the young, elderly, and chronically ill.   Pollutants associated with poor IAQ are grouped into the following five categories: 1) volatile organic compounds (VOCs), such as formaldehyde, pesticides, and cleaning products used in homes, schools and offices; 2) biologicals, which include molds, bacteria, and dust mites; 3) heavy metals, such as lead and mercury, found in paints and at illegal drug manufacturing sites; 4) combustion by-products, such as carbon monoxide, environmental tobacco smoke, nitrogen and sulfur compounds, and respirable particles; and 5) miscellaneous compounds, which include asbestos and radon. Indicators, based on these five categories, can be used to assess indoor air quality and to provide measures that effectively protect public health.

Direct and Indirect Indicators

Volatile organic compounds (VOCs)
Formaldehyde (HCHO) is a common chemical found in building materials. It is both a powerful irritant and possible human carcinogen. The direct indicator is the actual level as measured in the home or school. The indirect indicator is the presence of HCHO containing materials in the building. These materials are especially problematic when water damaged.

Organic solvents are used in a huge array of products commonly found and used in homes, schools, and offices. The misuse (e.g. lack of ventilation) or inappropriate use of these products can and has resulted in permanent health impairment. The direct indicator for this indoor contaminant is the measurement of solvent levels in indoor air. Indirect indicators are the use of solvent-containing products and receipt of solvent odor complaints.

The improper use and misapplication of pesticides can lead to serious illness. Direct indicators for pesticides are actual levels measured in the air of the affected building. Indirect indicators are the presence of the products in a home, or the measurement of serum cholinesterase levels in affected individuals. Also, see Pesticide Exposure Indicators.

Cleaning products are a very large category of compounds that can significantly contribute to poor indoor air quality and can adversely affect health. Because these products include such a large number of compounds, direct measurement of the individual compound producing the health effect may not be feasible. Instead, indirect indicators such as product use and the presence of product containers in a building may better serve to indicate IAQ problems associated with these compounds.

Biologicals
Dust mites may account for as much as 30% of all childhood asthma. The direct indicator is the presence of dust mites. Indirect indicators for dust mites include carpeted bedrooms, bedding without dust covers and high relative humidities (> 50%).

The presence of molds and bacteria in indoor air can contribute to poor IAQ and may be a significant factor associated with lost days from school and work. The direct indicator for this category is the presence of the offending agent. The indirect indicators for this group of IAQ contaminants are flood damaged materials, active water leaks, high relative humidities, and the presence of bird droppings on window sills and in attics.

Heavy metals
Mercury was commonly added to paints as an antimicrobial agent until 1990 and can be released into the air by repainting, washing and sanding. Mercury may also be an issue in homes that have been used as illegal drug manufacturing sites. Inhalation of mercury vapor is the most common route of exposure. Acrodynia or "pinks disease" is the outcome most commonly associated with moderately high dose exposures in children. In both children and adults, neuronal deficits can occur with elevated exposure. However, mercury is of most concern when young children (under two years of age) are exposed because the blood brain barrier has not yet matured. The direct indictor for mercury is the presence of the metallic vapor in air. The vapor can be measured using passive and active monitoring techniques. The indirect indicator for mercury is a home that has been painted before 1990, or a home that has been used for the illegal manufacture of methamphetamine.

Lead was once commonly found in interior paints and is a recognized health issue. Homes containing lead-based paints can have substantial levels of lead in house dust leading to the possibility of elevated blood levels. Ingestion of lead compounds is the most common route of entry. The young are most at risk for exposure to lead because of hand-to-mouth activity. Increased blood lead levels are associated with cognitive and developmental deficits which may be permanent. The direct indicator is measurement of the metal in the paint in the home. The indirect indicator for lead is a home that has been painted before 1976, or a home that has been used for the illegal manufacture of methamphetamine.

Combustion products
The by-products of combustion of organic materials contribute heavily to lung and vascular disease. These by-products include fine particulates, carbon monoxide, and the oxides of nitrogen and sulfur. Exposure to these compounds can lead to irritation of the upper airway and shortness of breath. Prolonged exposure at higher concentrations may lead to tissue damage in the airways and chronic lung and heart disease. The direct indicator for combustion by-products is the measurement of the compounds in the air. The indirect indicator for this category of compounds is the presence or absence of combustion appliances in the home.

Of the combustion by-products, carbon monoxide (CO) is the most dangerous and most likely to be found in the residential setting. Exposure to CO can result in death in as little as ten minutes. It has been associated with flu-like symptoms and is often overlooked as the underlying cause of illness. The direct indicator for CO is the concentration of the compound measured in the air of the affected building. The indirect indicator is the presence of a combustion appliance in the home or in an attached garage.

Environmental tobacco smoke (ETS) is a major contributor to childhood asthma, lung cancer deaths in non-smokers, and respiratory infections in children under 18 months of age. Children exposed to ETS are predisposed to chronic bronchitis. Adults similarly exposed can develop emphysema and heart disease. The indirect indicator is the presence or absence of a smoker in the home.

Miscellaneous compounds
Asbestos containing products were commonly used in homes and schools until the mid 1970s. The diseases associated with asbestos exposure include asbestosis, mesothelioma, and lung cancer. The direct indicator is the presence of friable asbestos containing products in the home. The indirect indicator is the age of the home.

Radon is a recognized problem in areas of eastern Washington and also along the Columbia River. Radon is a leading cause of lung cancer surpassed only by cigarette smoking. The direct indicator is the presence of radon in the home. The indirect indicator is the presence of the emitted alpha particles from radon decay.

Protective Measures

Source control, ventilation, and filtration are protection measures for IAQ related exposures. These three measures may be used separately or in combination to control almost all of the IAQ problems that commonly occur in residential and school buildings. Regulation of dangerous products is also a protective measure that works in specific circumstances. A protective measure for CO exposure is the installation of a commercially available detector. Education about products, the reduction of product use, and prudent product use would have a great impact on the number and severity of illness and injuries.

Access to Public Health Protection

Public health protections for IAQ are provided mainly to people in workplaces. Workplace IAQ must be monitored and controlled under industrial hygiene rules. Most of the indicators and threshold levels established for IAQ have been developed for men working in industrial settings and are based on exposures for average working hours. Many questions remain unanswered about IAQ. We still have a poor understanding about such issues as long-term low-dose exposures; the effects of exposures to multiple agents simultaneously; the effects on women and children; and the effects on immunocompromised individuals. Public health agencies do not monitor indoor air quality, except in response to complaints regarding schools. People are not provided public health protections for IAQ at residential and other privately used buildings. Low income individuals are often exposed for reasons such as dwelling location, type of rental property, and lack of proper dwelling maintenance. Education about IAQ is provided primarily in the form of informational bulletins through the news media and through seminars and conferences.

Indoor Air Quality Indicators

Disease/Illness/Injury	Causative Agent/Hazard (Direct Indicator)	Indirect Indicator	Protective Measures
Volatile Organic Chemicals			
Upper airway irritation, allergic skin reaction, asthma, cancer	Formaldehyde (HCOH)	HCOH source in home, especially water damaged materials	Regulation, education, source control measures, ventilation (direct exhaust and dilution), alternate product use
Transient intoxication, ears/nose/throat irritation, headache, nausea, vomiting, dizziness	Solvents	Product use	Alternate product use, regulation, education, ventilation
Central nervous system depression, headache, muscle weakness, nausea, drooling, tearing, staggering gait	Pesticide	Cholinesterase serum levels, product use	Alternate product use, regulation, education, integrated pest management, appropriate use
Ears/nose/throat irritation, skin irritation	Cleaning products	Product use	Alternate product use, education, source management
Biologicals			
Childhood asthma	Dust mites, molds	Carpeted bedroom, missing dust covers on bedding, high indoor relative humidities > 50%	Education, minimizing allergen exposure
Hypersensitivity pneumonitis	Molds, bacteria, bird related antigens	Flood damage, water leaks, relative humidity, roosting birds	Prompt flood cleanup, source control, humidity modification
Toxicosis, cancer	Fungal metabolites	High indoor relative humidities > 50%, flood damage	Source control, humidity control, proper flood cleanup protocols
Heavy Metals			
Acrodynia, cognitive impairment, motor damage	Mercury (Hg)	Home painted before 1990, illegal drug lab	Regulation, education, and source control and removal
Cognitive deficits	Lead (Pb)	Home painted before 1976, illegal drug lab	Regulation, education, and source control and removal
Combustion Products			
Cough, asthma, nausea, tachycardia, cognitive impairment	Combustion by-products	Gas, wood, oil used in home, CO levels	Education, prevention, design
Nausea, vomiting, headache, cognitive impairment, angina, cardiac	Carbon monoxide (CO)	Combustion appliances, back drafting, attached garage,	Education, prevention, commercially available detectors

Disease/Illness/Injury	Causative Agent/Hazard (Direct Indicator)	Indirect Indicator	Protective Measures
ischemia		carboxyhemoglobin levels	
See “Ambient Air Quality Indicators”	Nitrogen oxides, sulfur oxides, and particulates		
Childhood asthma and bronchitis Adult emphysema, heart disease	Environmental tobacco smoke	Smoker in the home	Education, smoking cessation, house free of cigarette smoke
Miscellaneous Compounds			
Asbestosis, cancer	Asbestos	Age of the home	Regulation, source removal and control
Lung cancer See “Radiation Protection Indicators”	Radon 222 (Rn)	Alpha particles	Regulation, source control, education

Zoonotic and Vectorborne Disease Indicators

Zoonotic diseases are transmitted from vertebrate animals to humans. Pet animals (e.g. dogs, cats, birds, reptiles), livestock (e.g. cattle, sheep, goats) and wildlife (e.g. bats, birds, raccoons, foxes, coyotes) serve as reservoirs of zoonotic disease transmitted to humans. Vectorborne diseases are zoonotic diseases. However, instead of being transmitted directly to humans from vertebrate animals, vectorborne diseases are transmitted to humans from animals via an arthropod (ticks, mites, mosquito, flea) vector.

Zoonotic diseases are caused by pathogenic microorganisms including bacteria, viruses, protozoans, fungal agents, rickettsia, chlamydia and nematodes. Human exposure to these microorganisms occurs in household, occupational and recreational settings. Vector control reduces human exposure by interrupting the transmission pathway of zoonotic disease.

Zoonotic diseases are transmitted from animals to humans through several different routes including ingestion, vectors, direct contact and inhalation. Each of the transmission routes are described below with examples of direct indicators (zoonotic disease), indirect indicators (events or signals which indicate cases could occur), and protective measures. Knowledge of the route of disease transmission helps to determine the appropriate protective measures needed to reduce potential human exposure and the number of human cases.

Transmission Via Ingestion

Transmission via ingestion occurs when the infectious agent or nematode is shed in animal feces or urine and is ingested directly, or indirectly in contaminated food or water. Salmonellosis, campylobacteriosis and giardiasis are examples of diseases transmitted to humans from pets, livestock and wildlife. Animals which shed these infectious agents may be ill or asymptomatic. Indirect indicators, which act as surrogates for agents producing illness in humans, include the number of animal cases of a disease, the number of exotic species imported, and extent of human cat contact. Handwashing after animal contact is the primary protective measure in households with pets. Another important protective measure is educating the public, petshop employees, school personnel, veterinarians, health care providers, and animal exhibitors about infectious agents, routes of disease transmission and methods of prevention.

Transmission Via Vectors

Vectorborne diseases are zoonotic diseases transmitted to humans via the bite of ticks, mosquitoes, fleas, flies and mites. Infectious agents responsible for disease include bacteria (e.g. Lyme disease, relapsing fever, plague), viruses (e.g. western equine encephalitis), rickettsia (e.g. ehrlichiosis) and protozoans (e.g. babesiosis). Wild animals, especially rodents and birds, act as reservoirs of infectious agents and serve as the source of infection for the arthropod vectors.

Examples of vectorborne disease transmission (reservoir, vector and host) are:

Reservoir	Vector	Host
Rodent ------------------------>	Tick ---------------------------->	Human
Bird --------------------------->	Mosquito ---------------------->	Human or horse

Lyme disease and relapsing fever are diseases transmitted to humans by ticks. Both diseases can cause mild to serious illness with the possibility of chronic health effects. Babesiosis and erhlichiosis are emerging tickborne diseases recently detected in Washington. Western equine encephalitis is transmitted to humans by mosquitoes and can cause mild illness (headaches) to serious neurologic outcomes with lifetime disability or death. Plague is transmitted by the bite of infected fleas found on various species of wildlife. Plague is capable of causing serious illness and even death in undiagnosed or untreated cases.

Indirect indicators are determined from information about the infectious agent, the vector and the reservoir host. Such information includes species distribution, prevalence of infection and population changes. Examples of protective measures for vectorborne diseases include avoiding vector habitats, using repellents, removing ticks, wearing appropriate protective clothing when in tick areas, and controlling mosquitoes and fleas.

Transmission Via Direct Contact

Transmission of zoonotic diseases by direct contact requires the presence of the infectious agent in animal body fluids (saliva, blood, urine) or tissues. Transmission occurs when an infected animal bites or scratches a person or when animal body fluids come into contact with a persons mucous membranes or open wounds. Rabies is the best known zoonotic disease transmitted to humans via an animal bite or scratch. Bats are the only recognized reservoir of rabies in Washington. Elsewhere in the U.S. rabies occurs in other wildlife such as raccoons, skunks, foxes and coyotes. This is of concern since these animals can be brought into Washington State. Animal rabies cases serve as an indirect indicator for human rabies. Protective measures include animal control programs, vaccinating dogs and cats for rabies, prohibiting importation of wildlife species known to carry rabies, and discouraging individuals from keeping wildlife as pets.

Animal bites result in an unknown number of injuries and some deaths each year in Washington. Several rare diseases besides rabies can result from animal bites or scratches involving humans. These include pasteurellosis, tetanus, potentially fatal herpes B virus infection (monkeys), and bartonellosis (cat scratch fever). Protective measures include: public education on animal bite avoidance, especially for children; animal control programs; and pet owner education about controlling aggressive animals and appropriate pet selection.

Infectious agents can be transmitted to humans from contact with animal tissues primarily in farm or livestock settings. These include *Brucella*, and *Coxiella burnetti* (Q fever) which may be shed in placental membranes of cattle, sheep and goats. Ringworm, a fungal infection, can be transmitted to humans from kittens, puppies and cattle. *Mycobacterium marinum*, a bacterial organism associated with fresh and saltwater fish and fish tanks, causes skin lesions in persons cleaning tanks. Education is the primary protective measure for preventing these diseases.

Transmission Via Inhalation

Transmission of zoonotic disease occurs by inhalation of infectious agents in contaminated dust or aerosolized animal feces, urine, saliva, or body fluids. The most well known zoonotic disease transmitted via inhalation is the *Sin Nombre* strain of hantavirus. The deer mouse, the most common rodent in Washington state, is the primary reservoir for this virus. Indirect indicators for hantavirus are the prevalence of infection in rodent populations and signs of rodent infestation in settings where people live, work and recreate. Psittacosis, a mild to serious respiratory disease in humans, results from exposure to infected pet or wild birds. Indirect indicators of psittacosis are pet bird illness or death. Other zoonotic diseases potentially transmitted via the inhalation route include: histoplasmosis, caused by a fungal agent which grows in soils and in large accumulations of bird and bat droppings; Q fever, caused by a rickettsial agent commonly shed by sheep and goats at birthing; and pneumonic plague, caused by a bacterial agent shed in respiratory secretions of infected cats.

Protective measures include education about rodent control, proper rodent infestation cleanup procedures, disease transmission, disease prevention methods, and precautions to follow when exposed to farm animals. Additional protective measures include the quarantine of imported birds, and education about appropriate respiratory protection during the cleanup of bird and bat droppings.

Access To Public Health Protection

Education is the primary protective measure for zoonotic diseases. However, for education to succeed, educational materials must be presented, produced and distributed in culturally relevant formats.

Adequately identifying appropriate protective measures begins with health agency surveillance and case investigations. For example, surveillance efforts for zoonotic diseases include determining the geographic distribution of mosquito and tick species in the state, the availability of exotic species for sale in petshops, the prevalence of infection in arthropod vectors, as well as the prevalence of hantavirus infection in deer mice. These surveillance measures are not currently being implemented.

Zoonotic and Vectorborne Disease Indicators

Disease/Illness/Injury	Causative Agent/Hazard (Direct Indicator)	Indirect Indicator	Protective Measures
Transmission via Ingestion of Animal Feces or Urine			
Gastroenteritis (diarrhea, vomiting, abdominal cramps, fever)	**Bacteria** *Salmonella spp.* *Yersinia spp.* *Campylobacter spp.* **Protozoans** *Giardia* *Cryptosporidium*	Animal cases of disease Increased # of exotic pets e.g. reptiles, hedgehogs, prairie dogs Increased exotic pet importations # of licensed animal dealers # of exhibits in public settings	Education e.g. handwashing after animal contact, avoid contact for certain groups (immunocompromised, infants) Restrict exotic pet importation Approved animal sources
Fetal neurologic injury	*Toxoplasma gondii*	Extent of human cat contact	Education e.g. avoid cat litterbox when pregnant
Neurologic injury resulting from larval migration	**Nematodes** (roundworms) *Toxocara canis* *Baylisascaris procyonis*		Handwashing after animal feces contact Restrict pets, wildlife from areas where children play Removal of feces Veterinary care for pets Veterinarian education
Headache, fever, liver and kidney disease	*Leptospira spp*. shed in animal urine		Restrict animals from drinking water sources and recreational waters. Education e.g. handwashing after animal contact
Transmission Via Vectors			
Tickborne			
Lyme Disease - skin rash, neurologic, cardiac, arthritis Relapsing Fever - recurring fevers Tularemia - fever, lymph node involvement Babesiosis - fever, chills Ehrlichiosis - fever, chills Tick paralysis - ascending	**Bacteria** *Borrelia burgdorferi* *Borrelia hermsii* *Francisella tularensis* **Protozoans** *Babesia spp.* *Ehrlichia spp*. **Toxin**	Tick species identification Monitor tick population changes Prevalence of infected ticks Identify animal reservoir	Education about: Avoid areas of tick habitat; Adequate clothing; Tick repellent; Tick removal (human and animals)

Disease/Illness/Injury	Causative Agent/Hazard (Direct Indicator)	Indirect Indicator	Protective Measures
respiratory paralysis, potentially fatal	toxin exposure from tick bite	Animal cases and ticks - dogs, livestock	
Mosquitoborne			
Western Equine Encephalitis (WEE) - asymptomatic to headache to severe chronic neurologic disease	WEE virus (arbovirus)	Monitor mosquito populations Mosquito species identification Virus presence in mosquitoes Sentinel bird studies e.g. chicken flocks Presence of horse cases	Mosquito control e.g. window screens, eliminate breeding sites, pesticide applications
Fleaborne			
Plague - fever, chills, lymph node enlargement, respiratory disease	*Yersinia pestis*	Mass animal deaths e.g. ground squirrels, rodents Monitor presence in reservoir wildlife species Pet animal cases	Flea control Rodent control Education e.g. avoid wildlife contact and burrows Restrict selling of prairie dogs for pets Investigate animal cases
Dog tapeworm - mild gastrointestinal illness	Dog tapeworm (*Dipylidium caninum*)		Flea control Veterinary care for pets
Carried by Flies			
Tularemia (see above)	*Francisella tularensis*		Fly control measures Education about avoiding deer flies
Gastrointestinal diseases	*Salmonella, Campylobacter Shigella spp.*		Fly control measures
Envenomations			
Anaphylaxis, tissue injury, irritation	Venom	Yellowjacket populations	Yellowjacket control
Transmission Via Direct Contact (Bites, Scratches or Contact with Body Fluids and Tissues)			
Rabies - fatal encephalitis	Various strains of rabies virus (*Lyssavirus*)	Rabies in reservoir animals e.g. raccoons, skunks, foxes, coyotes, bats Abnormal behavior in wildlife Population increase in reservoirs	Rabies vaccination for pets Education e.g. avoid wild animals Batproof buildings Animal control programs Restrict importation of reservoirs

Disease/Illness/Injury	Causative Agent/Hazard (Direct Indicator)	Indirect Indicator	Protective Measures
		Importation of reservoirs into WA	Investigate all potential exposures

Disease/Illness/Injury	**Causative Agent/Hazard (Direct Indicator)**	**Indirect Indicator**	**Protective Measures**
Pasteurellosis - cellulitis, fever Tetanus - neurologic toxin Capnocytophaga - potentially fatal in immunocompromised	**Bacteria** *Pasteurella multocida* *Clostridium Tetani* *Capnocytophaga Spp*.	Animal bite reports	Animal bite avoidance education Animal control programs
Traumatic tissue injury	**Virus** Monkey B *Herpes* virus	Monkeys kept as pets	Prohibit monkey importation or keeping as pets, education Appropriate pet selection
Ascending paralysis, permanent neurologic effects	**Bacteria** *Yersinia pestis* *Streptobacillis spp*.	Rodent/human contact	Rodent and flea control, avoid contact with wild animals/rats Education (petshops, animal dealers, pet owners)
Plague Rat bite fever	**Rickettsiae** *Bartonella spp*.	Cat/human contact	
Bartonellosis (cat scratch fever)	**Bacteria** *Brucella spp*	Livestock/human contact	Control cat fleas, avoid cat scratches (esp. immunocompromised individuals)
	Mycobacterium marinum		Education for high risk groups (veterinarians, farmers) to avoid exposure to livestock birthing membranes
Brucellosis	**Rickettsiae** *Coxiella burnetti*		Education about wearing gloves when cleaning fish tanks
Skin lesions	**Fungal** *Microsporum, Trichophyton*		
Fever, chills, pneumonitis			Education for high risk groups Avoid exposure to sheep during lambing season Avoid direct animal contact.
Ringworm			Veterinary care for newly acquired pets (puppies/kittens)

Disease/Illness/Injury	Causative Agent/Hazard (Direct Indicator)	Indirect Indicator	Protective Measures
Transmission Via Inhalation			
Headache, fever, shortness of breath, pulmonary edema Ranges from mild influenza-like to meningitis condition	**Viruses** Hantaviruses - *Sin Nombre* strain in western U.S. *Lymphocytic choriomeningitis virus* (arenavirus)	Presence of rodents (deer mice) in home, workplace, recreational areas Prevalence of infected rodents	Rodent control measures Education in avoiding exposure to rodent feces, urine, saliva and potentially contaminated dust. Education in cleanup and use of proper protective equipment for rodent infestation
Fever, headache, pneumonitis	**Rickettsiae** *Coxiella burnetti*	Livestock/human contact	Avoid exposure to sheep, goats during lambing season
Psittacosis	**Chlamydia** *Chlamydia psittaci*	Pet bird illness or death	Education in avoiding exposure to bird and bat feces, and in using respiratory precautions during cleanup
Mild respiratory illness to serious systemic disease	**Fungal** *Histoplasma capsulatum*	Cases of animal illness (dogs, cats)	
Plague -fever, chills, lymph node enlargement, pneumonitis	**Bacteria** *Yersinia pestis*	Sick cat/human contact	Veterinary care of infected cats

Pesticide Exposure Indicators

Every year, pesticides are responsible for many adverse health effects in Washington State citizens. Preventing exposure to these chemicals is important since these compounds can be acutely toxic, and several may have long term health effects following acute or chronic low-level exposure. Pesticide related illness can be grouped into three categories: 1) acute exposure resulting in acute effects, 2) acute exposure resulting in chronic effects, and 3) chronic exposure leading to chronic effects. Presently, the Department of Health carries out a surveillance program to monitor medical outcomes from pesticide exposure incidents with the goal of preventing pesticide related illness. Concomitantly, the Public Health Improvement Plan seeks to prioritize methodologies that will decrease the prevalence of deleterious outcomes, particularly, illness, injury and disease. Indicators provide the user with the powerful tools necessary to effectively engage in community or program assessments, support policy analysis and development, and evaluate assurance activities.

Acute Effects (Acute Exposure)

Organophosphorus insecticides are the class of pesticides most frequently associated with reported pesticide related illness in Washington. Insecticides in this class inhibit acetylcholinesterase enzyme in the nervous system. The enzyme is critical to proper nerve function, and compounds which impact this enzyme produce a broad spectrum of clinical effects indicative of overstimulation of the cholinergic system, including muscarinic effects (parasympathetic), nicotinic effects (sympathetic and motor) and central nervous system effects. Symptoms of overexposure include headache, salivation, muscle weakness, dizziness, blurred vision, abdominal cramping, diarrhea, excessive tearing, impaired judgment and miosis (pupil size). Severe overexposure can lead to respiratory difficulty, paralysis, convulsions and coma. There are two biomarkers in human blood for acetylcholinesterase, pseudo (plasma) and true (RBC) cholinesterase, which, when monitored, can be used as indirect indicators of exposure to organophosphorus pesticides. Also, for many of these compounds, monitoring of results from urinalysis of the pesticide or their metabolite(s) in individuals can be performed, and environmental samples can be obtained from the area where exposure occurred.

Carbamate insecticides are reversible inhibitors of cholinesterase. Initial signs and symptoms are similar to those observed with organophosphate intoxication, however, the recovery is much more rapid due to spontaneous reversal of acetylcholinesterase inhibition. Symptoms of exposure include blurred vision, weakness, sweating, miosis, headache, chest pain or tightness, salivation, and vomiting. Severe exposures can result in muscle cramps, pulmonary edema, areflexia and convulsions. The indirect indicators for human exposure to and possible poisoning from carbamate insecticides consist of the monitoring of results from urinalysis tests for the compound or the compound's metabolites, blood cholinesterase levels, and environmental sampling in the area where exposure occurred.

Herbicides, as a class, generally are considered less toxic to humans since they are produced to control weeds; which differ markedly in morphology and physiology from animals. Although there are numerous herbicides that have low toxicity in mammals, there are several chemicals which are highly toxic and have caused fatal poisonings in humans. Chlorophenoxy compounds such as 2,4-D have produced dermatitis, respiratory irritation, chloracne (severe dermatitis) and profound muscular weakness in individuals acutely poisoned. Dipyridyl compounds, which include paraquat and diquat, can result in dermatitis and gastrointestinal upset followed by respiratory symptoms and eventual liver and kidney damage. Lethal lung effects have also been observed with paraquat overexposure. Diquat poisoning produces similar effects with the exception that the marked effects on the lung are not observed. Many other herbicides, such as Roundup and Casoron, have low systemic toxicity but can act as irritants. Environmental samples can be obtained for those chemicals that do not quickly degrade. Indirect indicators for herbicide exposure are the results obtained from blood testing or urinalysis for the parent compounds or metabolites in individuals possibly exposed.

Fungicides are a heterogeneous group of chemicals that have not received a great deal of toxicological research as compared to insecticides. As a group, many of these compounds used to control fungus diseases on plants, seeds and produce are not systematically toxic under acute exposure conditions. However, there are exceptions such as the mercury-containing fungicides and those structurally similar to thalidomide, i.e. folpet. Although also used as an insecticide and herbicide, a portion of the 50 million pounds of yearly pentachlorophenol (PCP) production is used for fungicidal purposes. PCP is readily absorbed through the skin causing dermal sensitization as well as dermatitis and increases in metabolic rates. Known effects of human exposure include respiratory irritation, chloracne, hepatic porphyria, increased liver weight and increased liver enzyme induction. Another class of commonly used fungicides are the dithiocarbamates (ziram, thiram, mancozeb and maneb). Products in this class have low systemic toxicity but can cause irritation of skin, eyes, nose and throat.

Fumigants, which control insects, rodents and soil nematodes, are in gaseous form when exerting their pesticidal action and are used to fumigate hay, stored grain, shipping containers, soil and rodent burrows. Inhalation is the predominant route of exposure, although ingestion and dermal exposure may occur. Methyl bromide, as a fumigant, has caused death to individuals occupationally exposed, and survivors of poisoning have had symptoms that included malaise, headache, visual disturbances, nausea and vomiting. Effects due to inhalation have included acute pulmonary edema and neurological effects. In recent years, phosphine, which is released from aluminum phosphide and zinc phosphide in the presence of moisture, has replaced methyl bromide in many instances as a fumigant although it is more acutely toxic if inhaled. For both fungicides and fumigants, there are no convenient and accessible indirect indicators except that environmental samples can sometimes be obtained post exposure and for a select few compounds, urinalyses in individuals can be conducted.

Protective measures for all these compounds include state and federal regulations that insure worker safety and protection. Another protective measure is educating applicators, growers, operators, and the general public on the safe use and handling of pesticides. Also, the DOH surveillance program attempts to identify and target high risk populations so as to intervene using various protective measures.

Chronic Effects (Acute Exposure)

Along with inhibiting acetylcholinesterase enzyme, organophosphorus insecticides inhibit a second enzyme, neuropathy target esterase. Chemicals known to inhibit this enzyme include methamidophos, leptophos, fention and merphos. Severe inhibition of this enzyme is thought to play a critical role in inducing peripheral neuropathy [also referred to as organophosphate induced delayed peripheral neuropathy (OPIDPN)] 10 to 14 days after acute exposure. Although the effects on the motor and sensory nerves associated with this neuropathy can dissipate with time in individuals, cases with persistent severe effects have been reported. As a result, peripheral neuropathy is considered a chronic effect from acute exposure. Various studies, including those dealing with OPIDPN, conducted on individuals hospitalized with acute organophosphate poisoning have produced results indicating that these chemicals can produce chronic subclinical damage to the central and peripheral nervous system. Chronic effects include cognitive deficits (in sustained attention, memory and abstraction) and vibrotactile sensitivity.

Data presently available indicate that preventing acute organophosphorus insecticide poisoning may prevent chronic neurologic sequelae. The implication is that by preventing exposure that can produce acute effects, chronic illness will not occur. As a result, some of the protective measures used to prevent acute effects obtained from acute exposure are also beneficial in preventing chronic effects from acute exposure. The various tests and assays as described in the Acute Effects (Acute Exposure) section are not applicable for identifying chronic effects from acute exposure. Chronic effects could, in the future, be monitored via various administered neurological tests.

Chronic Effects (Chronic Exposure)

Effects of long term low level organophosphorus insecticide exposure have been studied with limited success in humans. Results from various studies have been suggestive but less consistent with each other, with some study results indicating that chronic exposure can produce subclinical effects on the central and peripheral nervous system. Observed effects have included neurobehavioural changes as well as vibrotactile sensitivity. The possibility exists that result differences may be due to different organophosphates studied. The dithiocarbamate fungicides are currently under scrutiny by EPA because they are considered possible human carcinogens.

Presently there are no adequate indirect indicators established to monitor illness, injury or disease. As with chronic effects from acute exposure, these effects could, in the future, be monitored via various administered neurological tests. Protective measures that reduce exposure, such as those described above, would be of benefit since deleterious effects (chronic or acute) can be minimized if exposure is minimized.

Access to Public Health Protection

The indirect indicators and protective measures described are the tools used to monitor the public for various diseases, illnesses and injuries and to protect the public from these outcomes. These tools, however, are limited under various circumstances. For example, the indirect indicators can only be of use if and when a pesticide exposure incident is reported. If overexposure occurs without the individual seeking proper health care, monitoring is not possible. These types of pesticide incidents resulting in manifestations that would be considered clinical, if diagnosed, can occur in the farmworker setting as well as in the home through individual use of pesticides. The safety standards used to protect workers are based only on avoiding acute effects from overexposure. However, since exposures do occur, little effort has been placed on studying chronic effects from exposure and developing protective measures for individual workers that address preventing these types of effects.

The surveillance program established by the Department of Health only intervenes on disease, illness and injury outcomes related to acute effects from acute exposure. Including chronic effect outcomes in the monitoring program could allow for increased prevention of pesticide related illness among Washington State residents.

Education can be a competent tool to aid the farmworker, certified pesticide operator and home user. These individuals will only benefit if they modify their behavior from receiving regular and proper education on the safe use of pesticides and about the warning signs and symptoms of overexposure to pesticides.

Pesticide Exposure Indicators

<table>
<tr><th>Disease/Illness/Injury</th><th>Causative Agent/Hazard
(Direct Indicator)</th><th>Indirect Indicator</th><th>Protective Measures</th></tr>
<tr><td rowspan="5">Acute Effects (Acute Exposure)
Effects of exposure to these chemical groups (causative agents) can result in some or all of the following:
malaise, muscle weakness, dizziness, sweating, headache, nausea,
vomiting, diarrhea, skin irritation, respiratory irritation and eye irritation</td><td>Organophosphate Insecticide (e.g. disulfoton, methamidophos, azinphos methyl, chlorpyrifos diazinon, malathion)</td><td rowspan="3">Foliar/aquatic and other environmental samples
Plasma and RBC cholinesterase levels (in humans)
Urinalysis of parent compounds/ metabolites (in humans)</td><td rowspan="5">Education
Personal Protective Equipment (L&I, WSDA)
Worker Protection Standards (L&I, WSDA, EPA)

Surveillance programs to identify & target high risk populations so as to intervene

Monitor & evaluate intervention strategies</td></tr>
<tr><td>N-methyl-carbamate insecticides (e.g. carbofuran, carbaryl, bendiocarb, methomyl, aldicarb)</td></tr>
<tr><td>Herbicides (e.g. dipyridyls, phenoxy compounds, carbamates, triazines)</td></tr>
<tr><td>Fungicides (e.g. thiocarbamates, EBDC compounds, organotin compounds, organic fungicides)</td><td rowspan="2">Environmental samples</td></tr>
<tr><td>Fumigants (e.g. methyl bromide, metam sodium, dichloropropene, zinc phosphide, aluminum phosphide)</td></tr>
<tr><td>Chronic Effects (Acute Exposure)
CNS & PNS sequelae (decreased neuropsychological performance, OPIDPN)</td><td>Some organophosphate insecticides (e.g. malathion, DFP, methamidophos, parathion)</td><td></td><td rowspan="3">Education
Personal Protective Equipment (L&I, WSDA)
Worker Protection (L&I, WSDA)</td></tr>
<tr><td>Chronic Effects (Chronic Exposure)
Possible CNS & PNS sequelae</td><td>Some organophosphate insecticides.(e.g. malathion, DFP, methamidophos, parathion)</td><td></td></tr>
<tr><td>Cancer</td><td>Fungicides (e.g. dithiocarbamates)</td><td></td></tr>
</table>